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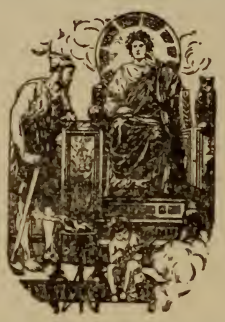

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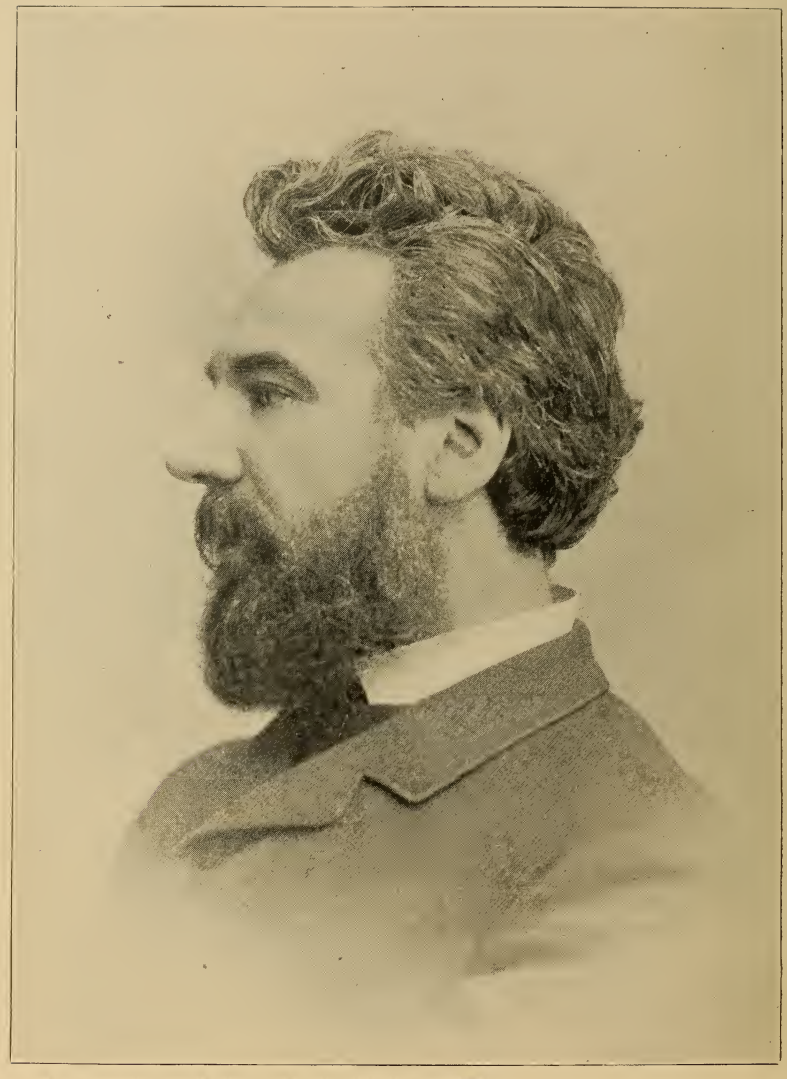

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THE TELEPHONE AND ITS OPERATION.

By Morgan Brooks.

THE fundamental telephone patent granted to Alexander Graham Bell, March 7, 1876, is unique among United States patents in that it has been held by the Courts to cover a broad principle rather than its specific application. It has heretofore been generally admitted that Bell's theory of the action of the telephone as explained in his patent was correct. Now, however, the researches of science convince us that there is no undulatory or other current,—in the sense of actual flow,—of electricity, any more than there is a current of light, as was once believed under the corpuscular theory, or a current of air in the production of sound. Bell's first claim, "A system of telegraphy in which the receiver is set in vibration by the employment of undulatory currents of electricity, substantially as set forth," falls to the ground if not scientifically correct. Could a patent for the ordinary speaking tube have been valid had it claimed the use of a *current* of air in transmitting speech?

The above consideration would limit the scope of Bell's patent to his specific instrument, the magneto-telephone. The most striking feature of this first practical telephone is its simplicity. It is identical with the telephone receiver in general use to-day, known also as the hand telephone. No important change or improvement has been introduced in it since the earliest days, and it "can now be made and used by anyone without any royalty," as publicly stated by the president of The American Bell Telephone Company.

The hand telephone is in fact a transmitter as well as a receiver. Fig. 1 will make its action more clearly understood. The voice produces air vibra-

MORGAN BROOKS, now president of the Independent Telephone Company of St. Paul, graduated from Brown University in 1881 and from Stevens Institute of Technology in 1883. He was subsequently employed on experimental work in the mechanical department of the American Bell Telephone Company.

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A TELEPHONE CABLE HOUSE AT A RIVER CROSSING.

tions which cause the iron diaphragm A to vibrate precisely as does one's ear-drum. The actual movement is very slight, but is sufficient to affect, inductively, the magnetism of the permanent magnet B, whose pole is close behind the diaphragm, and, hence, to induce in the coil of insulated wire, C, wound

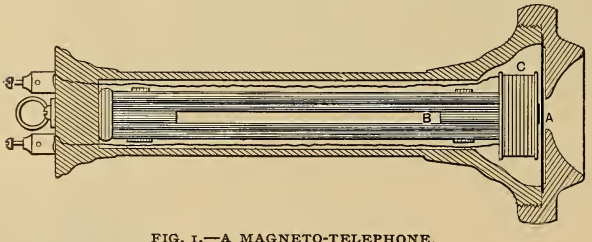


FIG. 1.—A MAGNETO-TELEPHONE.

around the magnet pole, electrical vibrations, which may be said to truly represent, in frequency and form, the vocal vibrations.

These induced waves of electricity, be they the simple result of a pure musical note sung into the transmitting telephone, or the complex result of articulate speech, are conducted over the line to the distant receiving telephone of similar construction, and, by a reciprocal process, affect the magnetism of that instrument, causing its iron diaphragm to repeat the exact vibrations of the transmitting diaphragm, and thus reproduce the tone, or spoken words, so that they may be heard by the listener. The reproduction is necessarily weaker than the original sound, owing to the various losses in transmission, and that it is audible at all is surprising, when we consider that no battery is used, and that the only power is the voice. The magneto-telephone, thus operated by the voice, is as truly an electric generator as the dynamo

driven by a steam engine. Although experiment demonstrated the possibility of carrying on a telephonic conversation, as above described, between New York and Boston, with no other instrument than a singe hand telephone at each end of the connecting line, it was evident from the first that something more

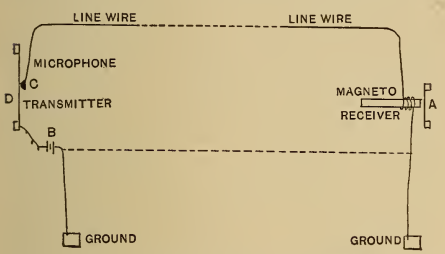


FIG. 2.—A SIMPLE MICROPHONE TRANSMITTER.

efficient would be required for extended commercial use. Inventors set about devising means for increasing the volume of sound, and the battery transmitter or microphone was the result.

The microphone is essentially a different instrument from the magneto-telephone, and must not be confounded with the primitive electro-magnetic telephone of Bell's 1876 patent. A capable of reproducing the original. sounds. A diaphragm, although commonly used, is not essential, since Prof. Hughes showed that three rusty nails could be made to transmit speech when an electric circuit is passed through their points of contact.

Fig. 2 shows a simple form of microphone transmitter, employing two electrodes in contact,—the thin carbon diaphragm D, and the point of carbon C. In passing through this microphone, whose resistance is controlled by the voice, the electrical energy of the battery B is made to vary in harmony with the voice and, when conducted over the line to the magneto-receiving telephone A, acts upon it in the same manner as if a magneto-transmitter were used.

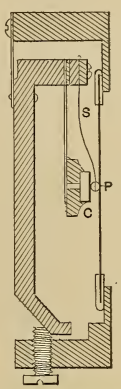
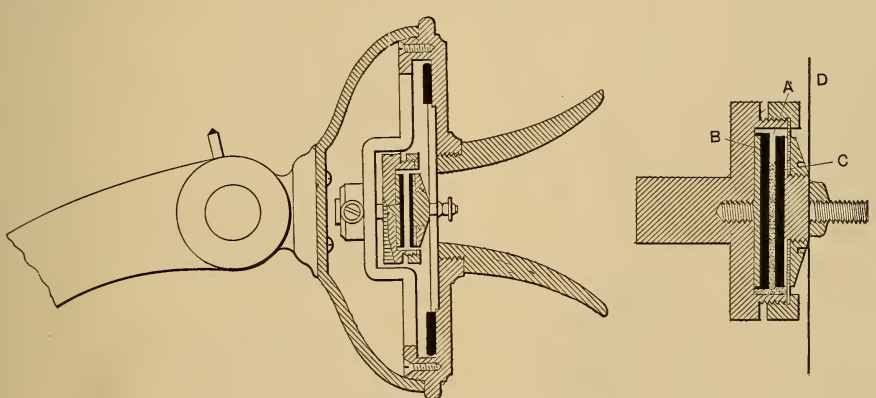


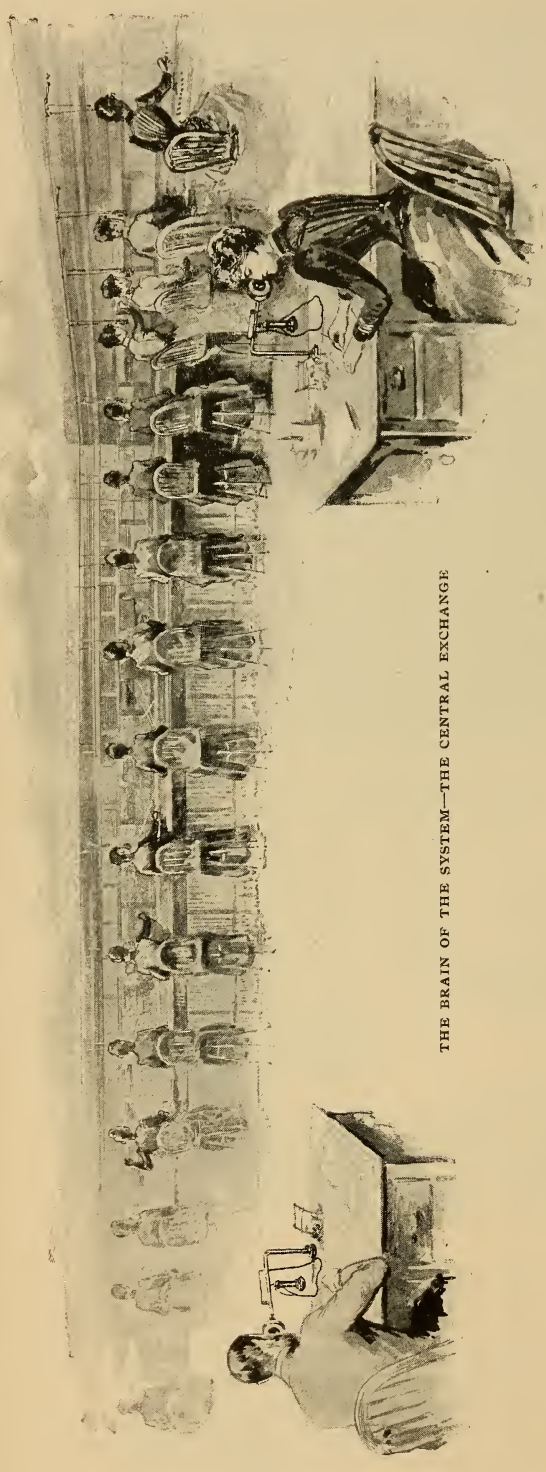
FIG. 3.—A BLAKE TRANSMITTER.

It is readily perceived that the loudness of speech obtained from the microphone does not, as with the magneto-transmitter, depend upon the



FIGS 4 AND 5.—A LONG-DISTANCE TRANSMITTER.

point of poor contact in the battery circuit is the characteristic feature of the microphone. This poor contact, when affected by sound waves offers a varying resistance to the passage of electricity, forming electrical vibrations strength of the speaker's voice, but upon the adjustment of the transmitter to the battery. It may fairly be compared with the case of a pipe organ, where the volume of sound is not dependent upon the strength of the



THE BRAIN OF THE SYSTEM—THE CENTRAL EXCHANGE

organist's touch. It is necessary to have a microphone transmitter and a magneto-receiver at each end of the line in order to carry on a conversation, since the microphone is not found to be a receiver satisfactory for commercial use. A battery at one or both ends of the line may be employed. This arrangement is all that need be desired for a short line, but when more than a few hundred feet long, the electrical resistance of the line wire causes a great loss in the volume of sound.

The difficulty is overcome in a very ingenious manner by the employment of the induction coil. This consists of two entirely independent windings of insulated wire, surrounding an iron core, which is preferably a bundle of small wires. In speaking into a microphone transmitter connected with the primary winding of an induction coil, the voice causes electrical vibrations, which, through this winding, affect the magnetization of the iron core. The magnetic variation in the core reacts upon the secondary winding, inducing corresponding electrical vibrations capable of reproducing speech in a magneto-telephone receiver connected with that circuit. Since the secondary winding has a greater number of turns than the primary, the reproduction has a greater electromotive force, thus overcoming the obstructing line resistance. Theoretically, the number of turns in the secondary should increase with the length of line, but, practically, standard coils are adopted. By the use of the induction coil the battery is confined to the local circuit, none being required upon the line.

The transmitter most extensively used in the United States, known as the Blake transmitter, is scarcely more complicated in construction than the type already described. As shown in Fig. 3, the circuit is not electrically connected with the diaphragm, but is led from the battery over the light spring S, to the platinum pin-head P, and thence to the carbon button C. This button, which is highly polished, is weighted to give it sensible inertia,

and is supported upon a slightly stiffer spring than that carrying the platinum pin-head. As will readily be seen, the platinum follows every movement of the diaphragm, while the movements of the weighted carbon are more sluggish, and the result is the desired variation of pressure, with little danger of complete separation of the electrodes.

The diaphragm, usually of sheet iron, is held upon a rubber band to give both electrical and mechanical insulation. The Blake transmitter, used with an induction coil, gives excellent results, except upon long-distance lines, where something still more powerful is needed. With its single point of contact, this instrument permits the use of but a single cell of battery. Multiple contacts have been tried, generally with little success, although transmitters of the Hunnings type, which employ pulverized carbon, are found to give great

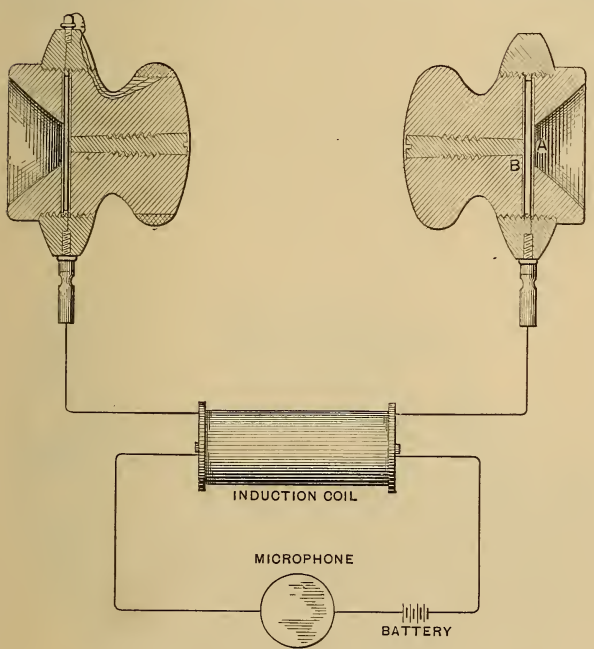


FIG 6.—DOLBEAR RECEIVER.

power when used with three or four cells of some acid battery.

Perhaps the most successful of the many forms of Hunnings' invention is the "solid-back," long distance transmitter, shown in Figs. 4 and 5. The carbon electrode C, attached to the

WHAT NUMBER?

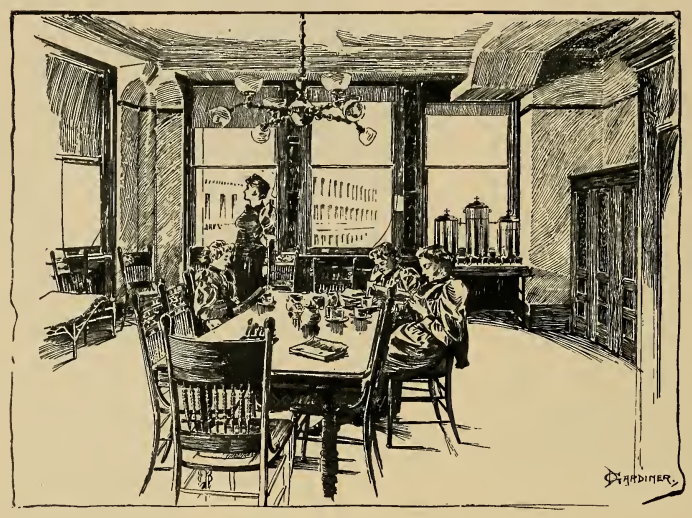
diaphragm D nearly fills the chamber A, in which is fitted another carbon electrode, B. The space between is filled with granules of a specially prepared form of anthracite coal, through which the battery circuit is carried. The details all relate to devices for preventing the carbon granules from "packing" or wedging themselves into the space provided and thus checking the proper vibration of the diaphragm. A small type of long distance transmitter, known as the granular button, is mounted upon a frame, similar to that of the Blake transmitter, and placed in a Blake box, so that it does not attract attention, although extensively used.

The telephone invented by Daniel Drawbaugh, as early as 1869, is of the Hunnings type, and is said to have given fair results, but it is proper to add that the successful use of this telephone was not proved to the satisfaction of the majority of the United States Supreme Court justices sitting

in the famous telephone cases of the year 1887.

In connection with any microphonic transmitter and a powerful induction coil, a form of non-magnetic receiver, invented by A. E. Dolbear, can be used. This receiver, shown in Fig. 6, consists simply of two metallic surfaces, A B, held parallel and close to one another, but not in actual contact. One is connected with the line wire, the other to the ground, or with anything having electrical capacity, *e. g.*, the hand. It is a simple form of condenser, having only two plates, one arranged to vibrate, and depends upon the attraction between the two surfaces, when one of them is electrified.

If connected as shown, without a complete circuit, either metallic or grounded, conversation can be readily carried on. Indeed, it is often a louder receiver than the Bell device. It has neither of the essential elements of the Bell invention—a magnet or a coil of wire—and would certainly have come into extensive use in competition with the Bell instrument had not the courts been made to believe it an infringement. Yet, how can an "undulatory current" exist in an open circuit?



LUNCH HOUR IN A CENTRAL OFFICE.

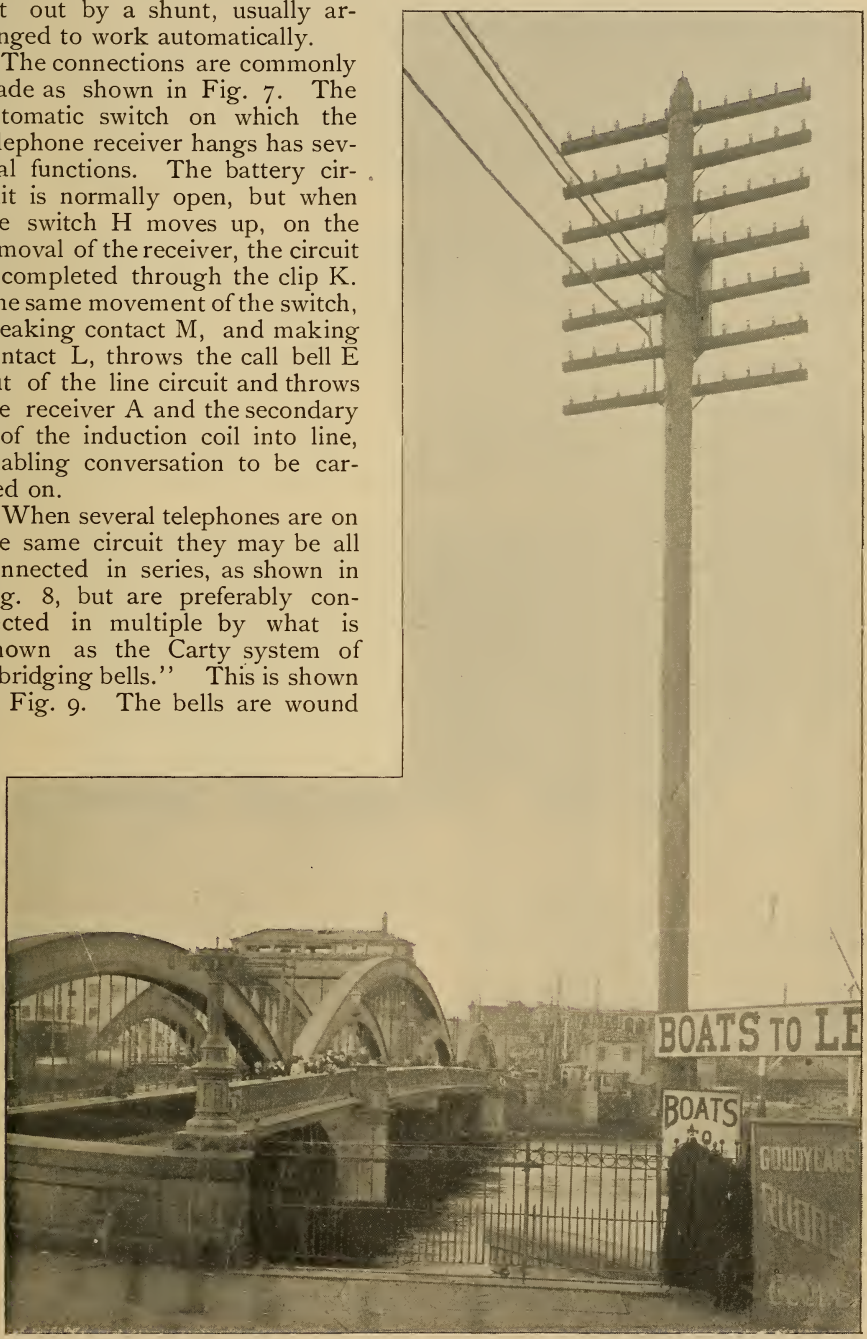
In addition to the telephone instruments proper, some form of calling device is usually required. In the early telephone days a battery vibrating bell was employed, but now the magneto-bell is generally used. The magneto-generator is a small electric machine similar to the early form of Siemens dynamo. It has a field, consisting of permanent magnets, and an armature connected without any commutator, so that, when rotated by the crank, the generator produces alternations like those of the magneto telephone, only they are comparatively slow, and, when heard in the telephone receiver, give a harsh, rattling sound. These electrical alternations actuate the hammer of a polarized call

RECEIVING COMPLAINTS AT THE WIRE CHIEF'S DESK.

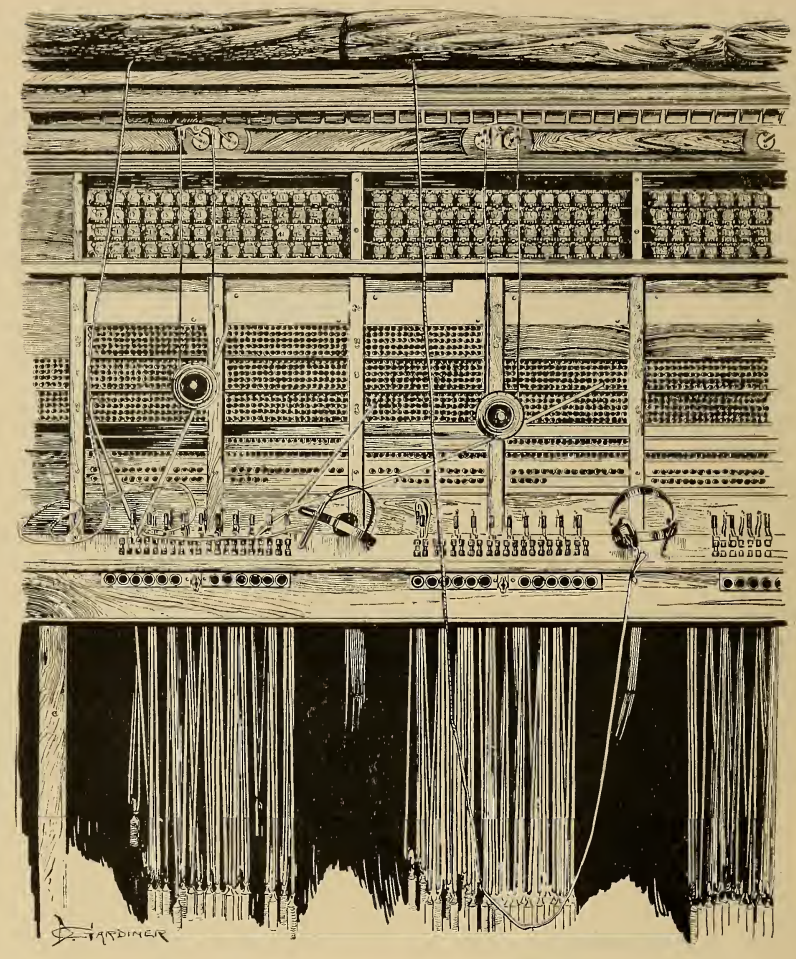
bell, and give satisfactory results over the longest lines. The resistance of the armature, when not in use, is cut out by a shunt, usually arranged to work automatically.

The connections are commonly made as shown in Fig. 7. The automatic switch on which the telephone receiver hangs has several functions. The battery circuit is normally open, but when the switch H moves up, on the removal of the receiver, the circuit is completed through the clip K. The same movement of the switch, breaking contact M, and making contact L, throws the call bell E out of the line circuit and throws the receiver A and the secondary S of the induction coil into line, enabling conversation to be carried on.

When several telephones are on the same circuit they may be all connected in series, as shown in Fig. 8, but are preferably connected in multiple by what is known as the Carty system of "bridging bells." This is shown in Fig. 9. The bells are wound to a very high resistance, so that when no one is talking all the bells take a



FROM THE POLE TO THE RIVER BED.



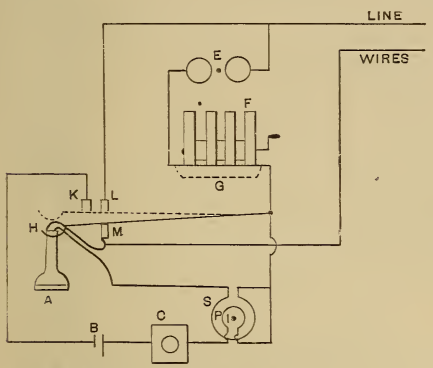
FRONT OF A SWITCHBOARD SECTION.

substantially equal share of the calling energy of the magneto-generator. As soon as the telephone is taken off the hook, however, the resistance through that telephone set becomes much reduced and the larger part of the talking undulations pass through the two telephones in use. This arrangement is a great improvement on the older method, as many as twenty telephones having been successfully used on one multiple circuit, while four or five are all that can well be used on the series plan. This is to the series method what the ordinary system of incandescent light wiring is to the series arc system.

For a larger number of telephones, the exchange, or central office, becomes necessary. The exchange is, theoretically, a very simple affair. It is the terminus of all the subscribers' lines of a given district, and the place where they can be connected for conversation. There are many ways in which this can be done. The simplest arrangement, used in some exchanges, has every line terminating in a flexible cord and plug, which can be inserted in a socket or spring-jack representing any other line.

When metallic circuits are used, double cords and plugs are required. It is, of course, necessary to provide some means to notify the exchange

operator that a connection is wanted. In the Law system there is a circuit for calling the exchange entirely independent of the subscribers' individual lines. It runs from the exchange operator's



A—Receiver or hand telephone.
B—Battery.
C—Microphone transmitter
I—Iron core } Induction coil.
P—Primary, } Induction coil.
S—Secondary. } Induction coil.
E—Polarized bell.
F—Magneto generator.
G—Shunt for same.
H—Automatic switch.
K L M—Clips for same.

FIG 7.—TELEPHONE SWITCH CONNECTIONS.

telephone to the stations of as many subscribers as one operator can serve. The subscriber switches his telephone out of its normal position on his individual line into the calling circuit to give an order to the operator, who is constantly listening. It is observed that the subscriber always has the operator at command, but that the operator cannot call a subscriber over the calling circuit. Should two subscribers demand attention simultaneously, one of

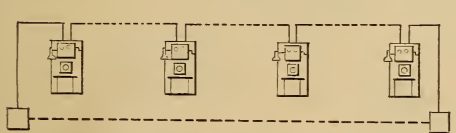


FIG. 8.—SERIES CIRCUIT.

them must wait a moment to avoid confusion.

The subscriber asking for a connection must first give his own number (as the operator has no means of knowing it), and then the number wanted. The operator makes the proper connections upon the switch-board and the individual lines are ready for conversation. The subscriber wanted can be summoned either by the exchange operator or by the calling subscriber, as is customary in England. It is necessary for the one who calls to notify the exchange operator over the special calling circuit when he has finished talking, as otherwise the lines might be left connected indefinitely. Law switch-boards are in use in a few of the large cities of the United States and give excellent service.

The Mann switch-board in England resembles the Law board, the chief difference being in the running of the calling circuit, which, in the Law board, takes the subscribers in series, whereas in the Mann it branches and takes them in multiple. Figs. 10 and 11 help to explain the arrangement. A very ingenious modification of the Mann system, due to Mr. A. R. Bennett, has been introduced with great success into

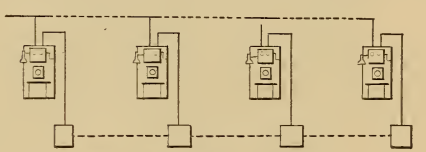
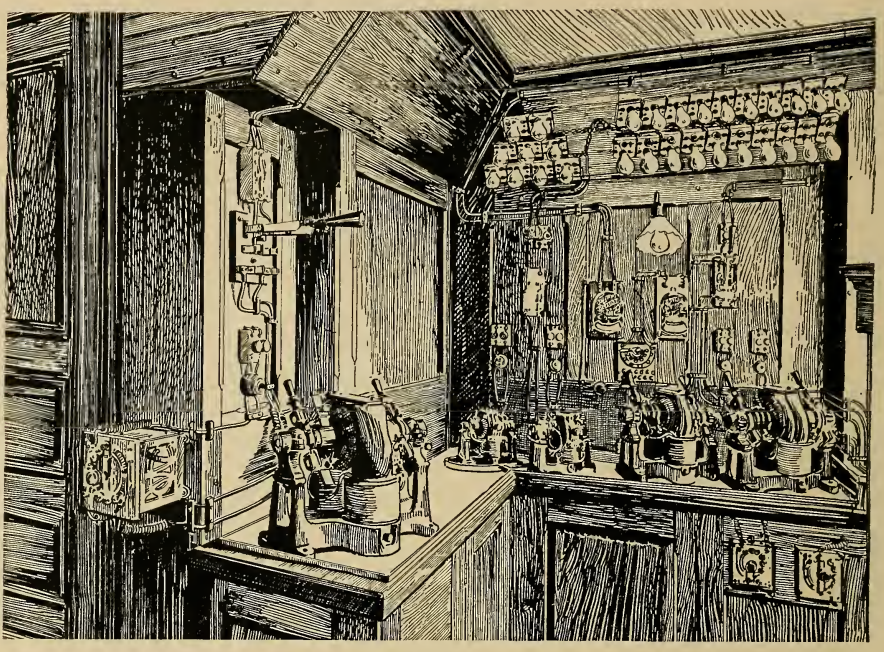


FIG. 9.—MULTIPLE CIRCUIT.

the Manchester Mutual Exchange in England. Bennett's calling circuit consists simply of a single wire, open at the far end, in a cable carrying the metallic circuits for a number of subscribers. It does not extend to the several subscribers' instruments at all, and the calling is done by static induction, making use for the first time of the enemy of the telephone—"cross-talk." In order to call the exchange, the subscriber grounds his metallic circuit, reducing it for the time to the equivalent of a single wire, and putting it in the best condition for cross-talk with the exchange operator. When the call is given, as in the Law system, the subscriber restores his circuit to the metallic, and is then connected over a circuit freed from induction. This plan does away with the chief objections to the Law and Mann systems, that they



CURRENT GENERATORS FOR A TELEPHONE CIRCUIT.

are expensive, and that any accident to the calling circuit may cut off a large number of subscribers.

In distinction from the above described boards, are those in common use on the annunciator plan. In these

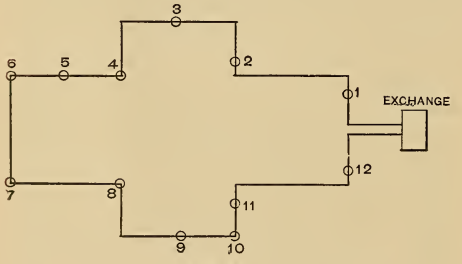


FIG. 10.—THE LAW SYSTEM CALLING CIRCUIT.

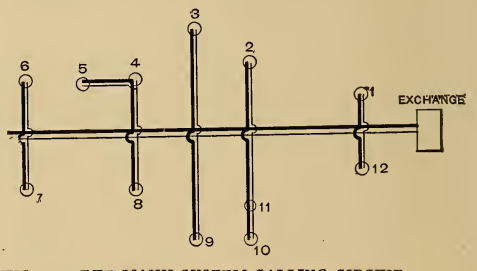


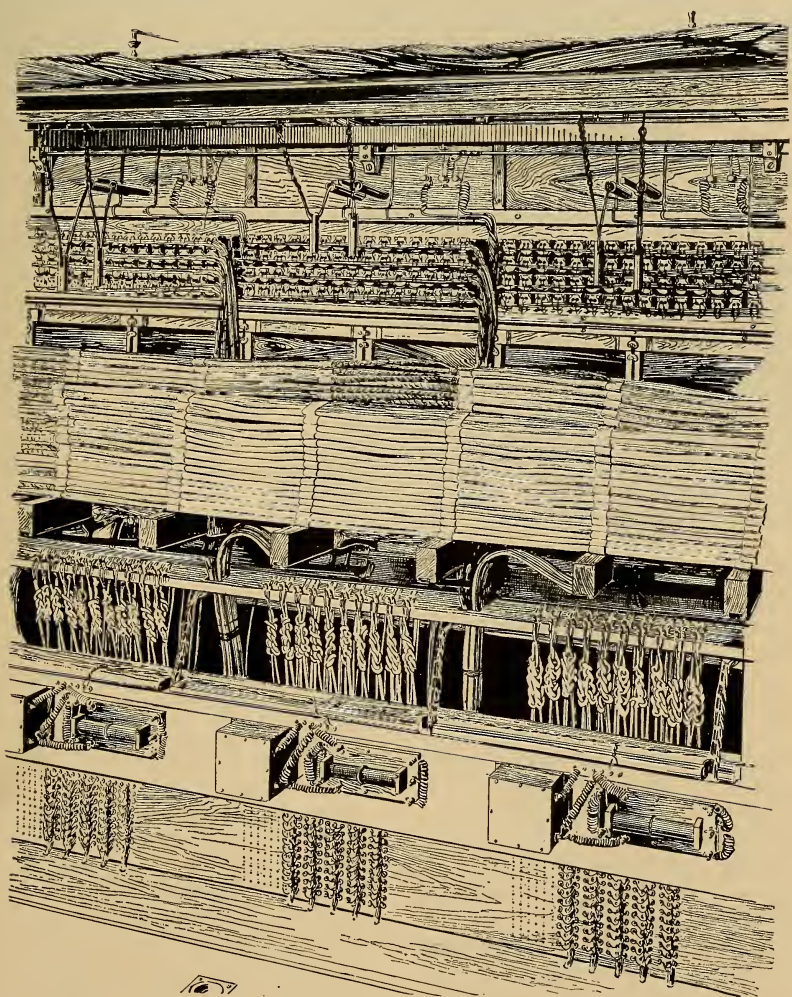
FIG. 11.—THE MANN SYSTEM CALLING CIRCUIT.

boards no separate calling circuit is used, the subscriber's generator or battery throwing a shutter or other annunciator device on the switch-board, indicating at once to the exchange operator the line which is calling. The Western Electric Co., in the United States, has elaborated this type of switch-board to the extreme in what is known as the multiple board. The multiple feature is the multiplication of the sockets representing the incoming lines, so that one socket of every line shall be within easy reach of every operator of the longest switch-board, thus permitting the most rapid working, since one operator can complete any desired connection.

A large telephone switch-board is divided into sections, each long enough for the accommodation of two or three operators and containing, in addition to a complete set of sockets, perhaps two hundred subscribers' terminals, represented upon the board by annunciator

drops. Upon seeing a drop fall, the operator inserts a plug connected with her telephone instrument by a flexible cord, in the corresponding socket or spring-jack, and asks the number wanted. Having received an answer, she inserts another plug, directly connected with the one first mentioned, in the nearest of the sockets representing the line called, and rings by pressing a key or push button connected with the ringing generator, kept constantly running. The two lines are now connected, and it only remains for the operator to turn a switch, cutting out her own telephone, to give the two subscribers unimpeded wires for conversation, as in the Law system. When they have finished talking, one or both "ring off," and an annunciator drop notifies the operator to disconnect the wires. Each multiple-board operator answers the calls of from 45 to 100 subscribers, the smaller number being that in the busiest exchanges.

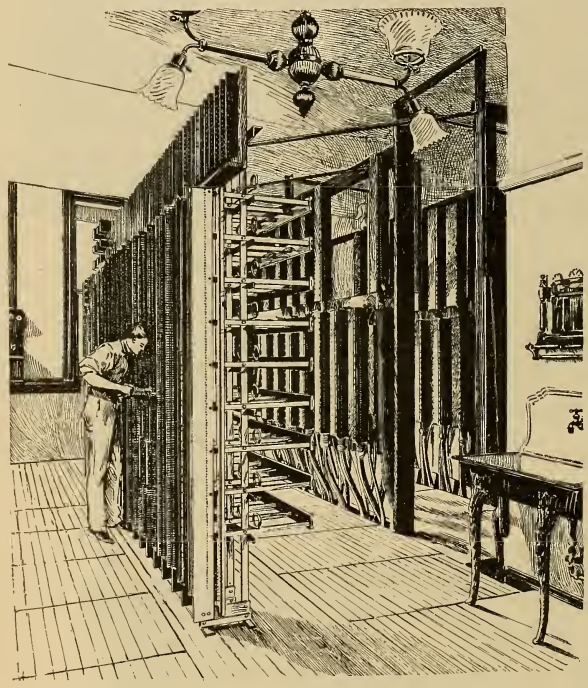
One more feature of the multiple switch-board, namely, the "busy test," remains to be described. It is necessary to provide means for informing the operator whether or not a line is in use



BACK OF A SWITCHBOARD SECTION.

at some other section of the board. The usual method is by means of a wire connecting together the metallic rings of every socket bearing the same number; hence there are just as many test wires as there are lines entering the board.

When a connection is made with any line, the test wire for that line and its several socket-rings, normally insulated, become grounded through the operator's plug, and a warning click will be given to any other operator trying the line. The click is produced by a battery connected through the operator's telephone to ground, the absence of a click indicating a free line.



A WIRE-DISTRIBUTING ROOM WITH CABLE TERMINALS.

In recent switch-boards the same battery that gives the busy test is used for the automatic restoration of the calling drops, reducing the work of the operator to a minimum. These boards are wired upon the "bridging bells" plan, which simplifies the connections materially. A novel method of connecting subscribers' lines, and for which a patent is about to be issued, avoiding the use of spring-jacks or other troublesome metallic contacts, provides means for bringing any two lines into such proximity as to permit conversation by induction. If the induction terminals are properly designed there is no appreciable loss in transmission.

Before entering the switch-board proper the in-coming subscribers' lines pass through the distributing board, where the connections are made for bringing any line to any given number on the switch-board. Here are also located the lightning arresters and the heavy current protectors, and an opportunity is afforded for making electrical tests of the lines when it is desirable to separate them from the board connections.

Lines connecting different exchanges, called "trunks," are treated upon the switch-board like subscribers' lines, except that they usually terminate in a "toll board," where record can be kept of out-of-town calls. Between busy exchanges trunk lines are divided into two sets, one set for out-going calls, the other for those coming in. Long trunk lines must be built not merely of two wires, but the wires must be twisted in pairs or otherwise systematically arranged to neutralize the induction so detrimental to good talking. The important discovery made by Mr. J. J. Carty that the most troublesome induction is electro-static, rather than electro-magnetic, as previously supposed, has modified the rules for arranging metallic circuits upon pole lines to the great improvement of the telephone service.

The "long distance" overhead lines of the Bell Company are well known as examples of the best possible line construction, no expense being spared to make the conditions perfect. As a re-

IN A CENTRAL OFFICE.

sult these lines have withstood storms which have thrown the wires of the telegraph companies entirely out of service. Underground wires are always avoided if possible in telephone service, not only on account of expense, but also because of the retardation due to electro-static capacity, which seriously limits the distance to which sound can be transmitted by electricity.

The speed of telephonic transmission, being that of electricity, is practically instantaneous over the longest lines we have. It may be interesting to consider that if the sound waves were themselves transmitted over the wire, even at the high rate of two miles per second as in copper, eight minutes would be required for a word to travel from New York to Chicago, and conversation would be impossible. For long lines copper is now used exclusively, and it should be used for short lines as well, since it is not only superior in all re spects to iron, but is actually cheaper if measured on the basis of equal conductivity.

While metallic circuits are fast coming into general use, there still remain a great many grounded circuits, and if connected directly together the value of the metallic circuit in suppressing inductive disturbances is lost. But if a "repeating coil" is used the advantages of the metallic circuit are retained. The repeating coil is a special form of induction coil, preferably with closed magnetic circuit, in which the primary and secondary have about the same number of turns of wire. One circuit is connected with the grounded line, the other with the metallic circuit, and talking is carried on by induction. These coils are now so perfect that there is little loss in transmission, even with two in use at one time, as in the case of a metallic trunk line with grounded lines at each end. It is found that repeating coils may be used to advantage in the construction of long lines not wholly metallic. The metallic circuit may, for example, be carried from the exchange beyond the influence of an electric railway line, and joined through a coil to a long single wire running to some distant country subscriber.

Several schemes for overcoming the troubles of grounded lines, without going to the expense of doubling all wires, have been devised. Probably the most successful of these is the McCluer system, in which a carefully proportioned, common return wire joins the ends of a number of single wires, doing away with ground connections altogether.

The problem of multiplex telephony, or the transmission of several messages simultaneously over the same line, has attracted much attention. The well known methods used in telegraphy do not apply to the telephone, and of the many plans suggested none has proved a commercial success. One system for combining telegraphy and telephony upon the same wire, that of Van Rysselberghe is in extensive use in Belgium. A satisfactory solution of the multiplex problem would cause the immediate extension of telephone trunk lines and their rapidly increased use, since the rates for distant connections could be reduced from their present almost prohibitory scale. While the limit of telephonic conversation by land lines has not yet been reached, submarine conversation is, at present, restricted to about one hundred miles. Our descendants may talk across the Atlantic, but certainly not through cables constructed like those now used for the telegraph.

The stimulus given by the expiration of the original Bell patents and by the recent cancellation of the Berliner patent encourages the expectation of further advance in telephony. While the American Bell Telephone Company holds a well-nigh impregnable position as regards long-distance lines and exchanges in the larger cities, there remain to those now entering the field the vast reservations just opened to the public of private lines and exchanges for villages, factories, hotels and public buildings, a field the fertility of which is as yet little understood.

HELLO!

CAST-IRON WATER PIPE.

Its Use, Manufacture, Tests and Inspection.

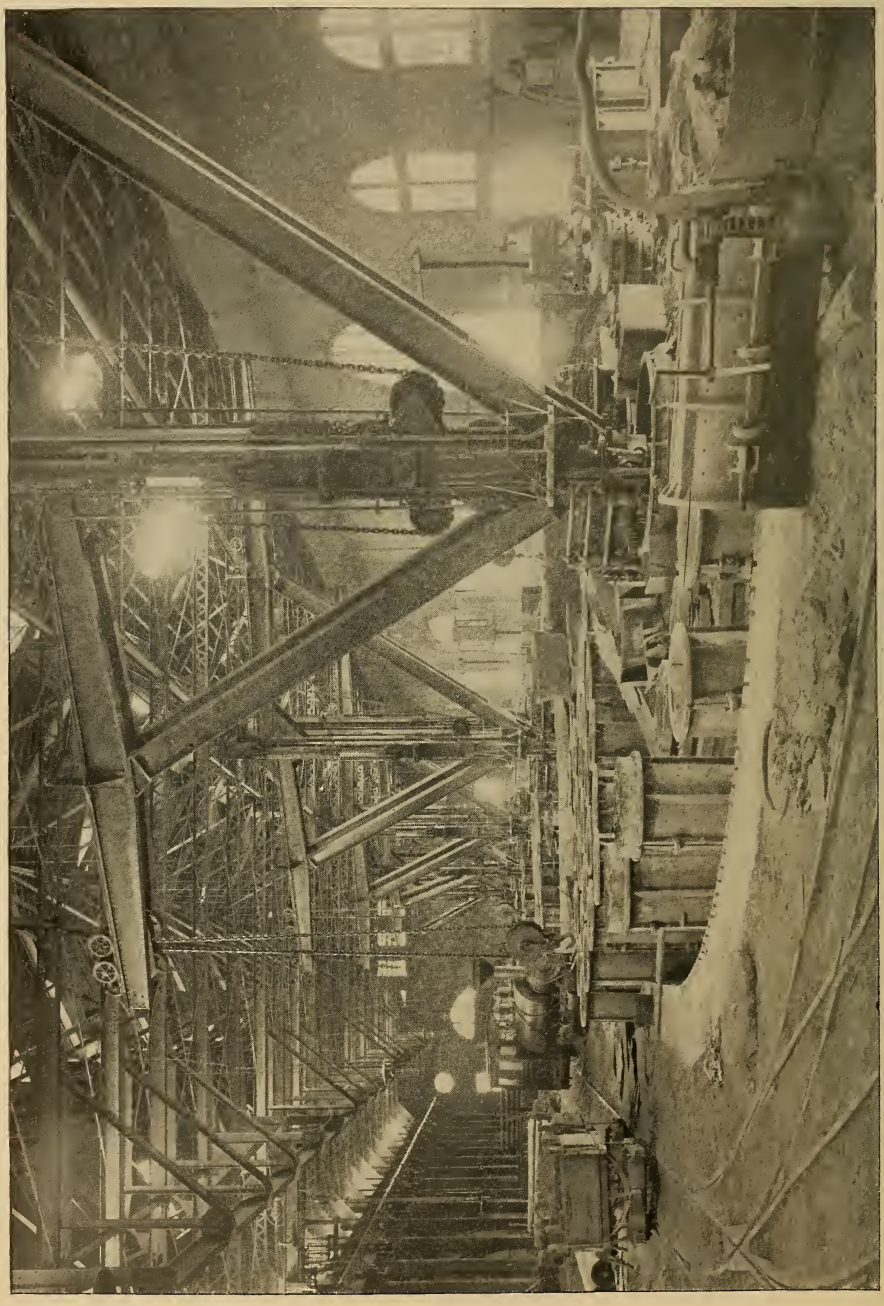
By Frederick H. Lewis.

Frederick H. Lewis received the degree of civil engineer at the University of Pennsylvania in 1878. After a short service on the U. S. Coast Survey he devoted seven years to railroad engineering. For the past eight years he has devoted his attention exclusively to the testing of materials and the supervising of contracts for work to be made to plans, specifications and tests. He is a member of the well-known firm of Booth, Garrett & Blair, whose laboratories at Philadelphia were the first commercial testing laboratories in America.

THE first works for a public supply of water in the United States were built at the city of Boston in the year 1652, and nothing further was done in this direction for more than 100 years. At the present time, for not less than 25,000,000 of Americans the question of water supply presents no difficulties. For domestic use, for business purposes, or for fire protection, an abundant supply is to be had at the turning of a valve.

Not only is the supply abundant in most cases, but the use of it reaches extravagant figures. In the year 1894, Chicago used 238,000,000 gallons of water per day, and Philadelphia, 197,000,000 gallons. All this water was pumped from the source of supply to reservoirs or standpipes for distribution. The city of New York has a gravity supply of water and uses 183,000,000 gallons per day. On the basis of these figures, it appears that every man, woman and child in Philadelphia requires 160 gallons of water for daily use; in Chicago, about 150 gallons, and in New York, about 95 gallons. In some of the smaller cities the per capita consumption reaches even higher figures. Thus, Buffalo is on record, in 1890, with a daily consumption per capita of 186 gallons, and Allegheny, Pa., at the same time, with a daily per capita of 238 gallons. If these figures are compared with the per capita consumption of the city of London—40 gallons per day—it will be seen what lavish use is made of water in American cities, and some conception will be formed of the great system of works required to supply such demands.

So much accustomed have people become to this abundant supply and lavish use of water, that few ever consider how it is placed at their disposal. They have a general idea that it comes from "the water-works," but few have any conception of the magnitude of the plants which supply their wants. A summary of the general facts will, therefore, be interesting. The cost of water-works of the United States is estimated to be nearly, if not quite, $550,000,000, to supply the needs of about 2100 cities and towns. In mains alone, there are something like 35,000 miles of pipe, laid chiefly in the beds of the streets and highways. If we consider, besides, the great systems of laterals, branches and service pipes, and the enormous number of valves, branches, tees and other special castings required to complete these works, we begin to get some adequate idea of the extent of these water-works systems, and to appreciate what enormous bodies of water are safely conducted under the beds of the streets



A PIPE FOUNDRY WITH FIVE CASTING PITS.

and distributed over areas of many square miles. Much the greater part of this water is pumped, some of it to elevations as great as 500 feet, and it often passes through miles of pipe before its discharge through a spigot.

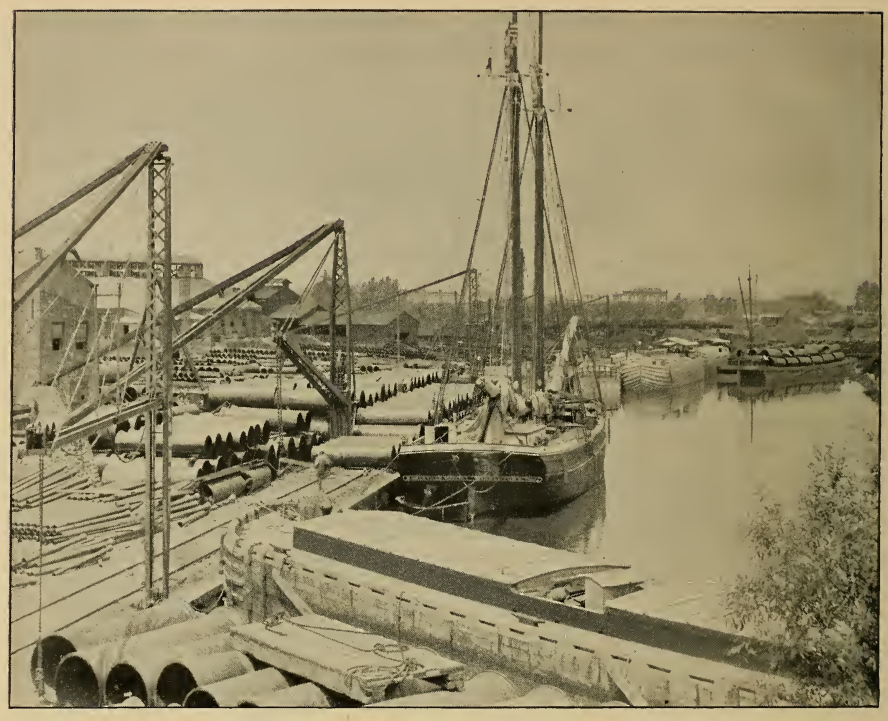
Speaking broadly, this entire system of works may be considered to be constructed of cast-iron, and for years past the manufacture of pipes and special castings for water-works has been much the largest industry in which cast-iron is a finished product. The exact amount varies considerably from year to year, but it certainly reaches at least 500,000 tons per annum. The United States census of 1890 gives the consumption of pig iron in the pipe foundries alone as 590,000 tons. This means a national bill of somewhere between $10,000,000 and $15,000,000 a year for water pipe, a sum sufficient to create a large industry.

As a result of this large consumption of a product which, in essentials, is standard in design and method of manufacture, the pipe foundries have become highly differentiated plants, adapted and developed with special reference to their product. A description of such an industry has, therefore, considerable interest, because of the unique character of the plants, and because of the important relation which it bears to the output of finished cast-iron work. The subject is especially interesting at this time, when it has possibly reached its maximum development. The use of cast-iron in street pipes will doubtless continue indefinitely so far as we can now see ; but for long pipe conduits, and for heavy mains, it now seems evident that the riveted steel pipe is to supplant cast-iron, and perhaps to such an extent as to limit the further development of the cast-iron pipe product. The long lines of riveted steel mains, which in recent years have been used in the water supplies of the cities of Newark, N. J., Rochester, N. Y., and Portland, Ore., certainly suggest that wrought metal, which has supplanted cast-iron for so many other purposes, is about to do so in water mains.

It is the purpose, therefore, of the writer to describe the general features of pipe foundry plants, and the methods of tests and inspection which have been in vogue for years past to insure that great systems of mains may safely conduct water through the streets of the larger towns and cities. A pipe foundry does not realize economy of production through any novel methods of foundry practice. The economy results from the manufacture of a great many pieces which are essentially alike. The 12-foot laying length for cast-iron pipes has been adopted as the standard of all foundries, and practically all pipe mains have the bell and spigot joint, made tight by hemp packing and a lead ring. There is more or less difference in the practice of different engineers in the design of the sockets and bell ends of pipes, but as this affects comparatively a small part of the mould, provisions for variations of this kind are readily made. For each size of pipe, therefore, the flask, core barrel and the patterns can be made once for all in cast-iron, and used indefinitely. The base casting and the bell and socket moulds require occasional changes to provide for the difference in standards mentioned above, but these constitute the minor parts of the completed pipe mould.

The most striking feature of a pipe foundry is the circular casting pit, dominated by its large radial crane. The pit around the crane is sunk about 13 or 14 feet below the floor, so that a completed flask for a 12-foot pipe will be about at the floor level, and the crane must be high enough to lift flask and pipe clear of everything, and swing it all around the pit. Around this pit all the work of the foundry proceeds, and the scene is one of great activity and continuous interest.

A completed pipe mould consists of four parts : 1st. The base casting, which carries also the socket ring (for pipes cast bell down) ; 2d. The flask proper ; 3d. The core which fits into the socket ring below and is centred by wedges at the top of the flask ; and, 4th. The bead ring which fits snugly around the top of the core and forms the mould for the bead at the spigot-end of the finished



A PIPE YARD AND WHARF.

pipe. The moulding of the sand to these different parts constitute as many different processes, the moulding around the flask alone being done in the pit. The process of moulding, then, is as follows : The cast-iron flask, which is in several parts, bolted together, is set up in the pit and secured on a base casting which constitutes the pattern for the outside of the bell of the pipe. A mandril is then lowered into the flask, fitting into turned bearings in the base, and at the top it is properly centred and wedged in place. The sand is then shoveled into the space between the mandril and the flask, being thoroughly rammed as it is put in, thus making the mould for body of the pipe by the use of permanent patterns.

In the meantime a spindle, which constitutes the core barrel, has been set in lathe bearings at one side of the foundry, and covered first with a layer of hay rope and then coated with damp sand, which is trued to diameter and outline by a mould board. At still a third point of the foundry, the base and socket rings are being moulded with standard patterns ; and at a fourth point the bead rings are made. All parts of the mould must then receive a facing of lamp black, and must be separately dried. A drying furnace is provided for each of the parts, and in well-regulated foundries the work on all four parts goes forward harmoniously, so that bases, cores and bead rings are already to go into place as soon as the flasks are dried and in condition for casting. It will be readily seen that a process which is thus essentially simple, and in which nearly all parts of the flasks and of the moulds can be used over and over again, will realize a great economy of production ; and it is through a careful development of the economics of this process that cast-iron pipe can be sold with profit at a price of from ¾ cent to 1 cent a pound, while the ordinary run of castings may cost from 2 to 5 cents.

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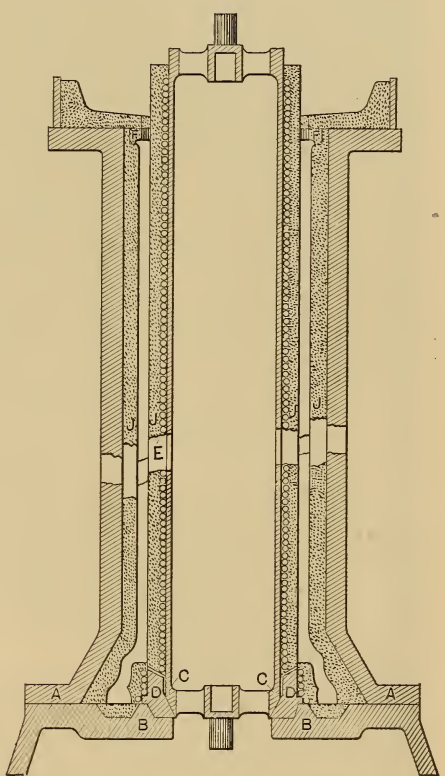
The casting pit and the foundry around it present an interesting scene when the work of the foundry is under full headway. In the pit, the moulding in the flasks, the baking, assembling of parts, casting of pipe, and withdrawal of cores, pipes and burned-out moulds proceed in regular order and in a continuous round. The number of casts varies according to the size of the pipes, the facilities of the foundry and the skill of the foreman.

The cupolas for melting the iron differ little from those used in other founderies. The ladle containing the molten metal is handled by the pit crane, and the pouring of the iron must be done rapidly and at a high temperature. In what appears to be a very short time after casting, and while the pipes are still at a cherry red heat, the core spindles are drawn, generally stripping free of sand and of hay rope as they come out. The pipes are taken out while still red-hot, and as soon as they are cold enough, are placed in line on the cleaning skids. The flasks are then knocked apart and cleaned up, and the process of moulding for cores and flasks is again begun. Thus, in continuous round, the work of the foundry proceeds, and the output of single pits is often as much as 75 tons, and sometimes more than 100 tons per day of 10 hours.

When the cast-iron pipe has been drawn from the mould, it is, in the best modern foundries, placed on a long line of skids which is at right angles to the length of the foundry, and the pipes proceed on these skids, one after another, through a course as follows: 1st. Through the cleaning shed ; 2d. To an oven, where they are heated to a temperature of about 500° F. prior to dipping ; 3d. To the dipping tank, where they receive a tar coating ; 4th. To the hydraulic proving press ; 5th. To the scales ; and 6th. To the loading skid, or to the yard if not required for immediate shipment.

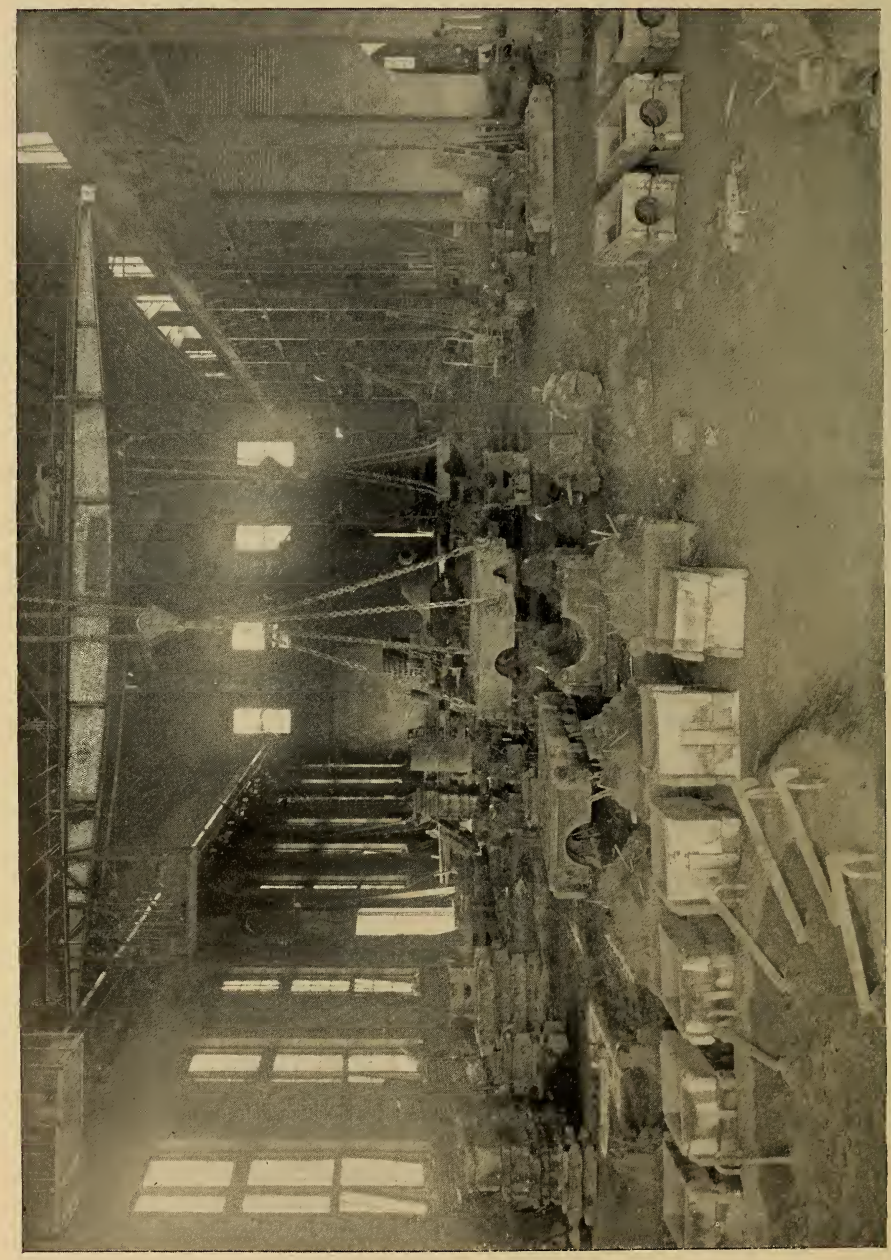
When a water pipe is laid in the bed of a street, it must not only conduct water without leaking, but must resist large stresses on the material. There is, first, the static head or pressure of the water, which varies in different systems from a few pounds to over 200 pounds per square inch. Then, there is an added pressure when the flow of the water is suddenly stopped or checked, which is known as water ram, and which is commonly assumed to be about 100 pounds per square inch in large pipes, and somewhat more in smaller ones. These pressures are from within. In addition to this the pipe has to resist the outside pressure of the earth around it,



A PIPE MOULD.

tending to crush it. This latter force is generally opposed to the other forces which tend to burst the pipe, but must be considered and in some cases specially provided for in designing castings.

A first-class water pipe must not only resist these pressures, internally and externally, at the time it is made, but must



A LOAM FOUNDRY.

continue to do so for a long term of years. The consequences of bursting a large water main in the business district of a city are most disastrous. In a recent instance, the damage to the street and loss of merchandise through the flooding of cellars was estimated at over $10,000 during the hour or so which it took to close the valve in the main leading to the break. It is for these reasons that it has been the custom for 20 years or more past to have all water pipes for the larger cities inspected and proved under hydraulic pressure, and to require, besides, that the pipe shall be cast from iron of such quality as to withstand specified tensile and transverse stresses. The work of an inspector charged with such duties is, in many respects, more interesting and makes greater demands on good judgment and experience than any other work which inspectors of material are called upon to perform.

A casting of any kind must be examined with greater care than is necessary for a piece of rolled or wrought metal, because it is not only necessary to examine the surface, but to form a satisfactory opinion of its internal structure. A pipe casting, by reason of its great length and superficial area, is a specially difficult casting to inspect, as it is a difficult casting to make. The comparatively thin shell may be defective at almost any point, and from a dozen or more distinctively different causes.

An inspector in charge of such work always begins his daily task in the cleaning shed, where each pipe, in turn, is examined inside and out, is gauged with calipers to determine the thickness of the shell at each end, and to prove also that the core and mould have been set concentrically. Then each socket must be carefully examined to see that it is free from obstructions or scabs, and that it is round and has the proper clearance for the spigot-end of another pipe to enter. This has to be determined by the use of an inside circular gauge which must pass freely to the bottom of the socket.

At the spigot-end an outside circular gauge is used, which must pass freely over the bead without striking at any point, so as to insure that it will freely enter the socket of any other pipe. A sharp-pointed steel hammer is used freely on any part of pipes where blow holes, or sand holes or cinder pockets are suspected. It may be well imagined that it is no easy or pleasant task to thus examine 30 or 40 great pipes in the course of a morning in the midst of the dirt and dust of the cleaning shed, and in contact with the rough and dirty surface of the iron ; but it must be done and thoroughly done.

Let us then start with an inspector at the bell end of a row of pipes and observe how his work is done. First, the bells must be clean and sound. Usually they are cast bell downward, so that they will be sound, but each pipe must be thoroughly examined and tested with a hammer. Second, the inside of the bells must be of correct diameter, truly round, and free from scabs and obstructions, so as to allow all accepted spigots to enter freely and have the required lead room all around. This is determined with a circular gauge referred to above. Very little latitude can be allowed in the inside diameter of the sockets. The outer diameters of the beads on the spigot-ends of pipes are usually but $\frac{1}{8}$ inch less than the inside diameters of the sockets, and as the beads are apt to be large, sockets must measure the full required diameter at all points, but may overrun $\frac{1}{8}$ inch without objection. The lead space back of the bead varies from $\frac{1}{4}$ inch on small pipes to $\frac{1}{2}$ inch or more on large ones, and must be clear. This is especially true of the recess or so-called lead ring inside of the socket, which is intended to wedge the lead in place, and to prevent it from being forced out under pressure.

Third, cores and moulds must be set concentrically, that is the bells and the pipe barrels adjacent to them should caliper the same thickness all around. It is customary to gauge the thickness at four points, 90 degrees apart, around the circumference. A variation of 1-10 inch plus or minus from the required gauge may be allowed in the thickness of the pipe-shell, provided the weight of the pipe is correct, that is, the eccentricity

of the core may be 1-10 inch as a maximum allowance. It would seem as though this were not a difficult requirement to meet, yet a great many pipes are rejected because of uneven gauge, due to the fact that the core has not been properly centred.

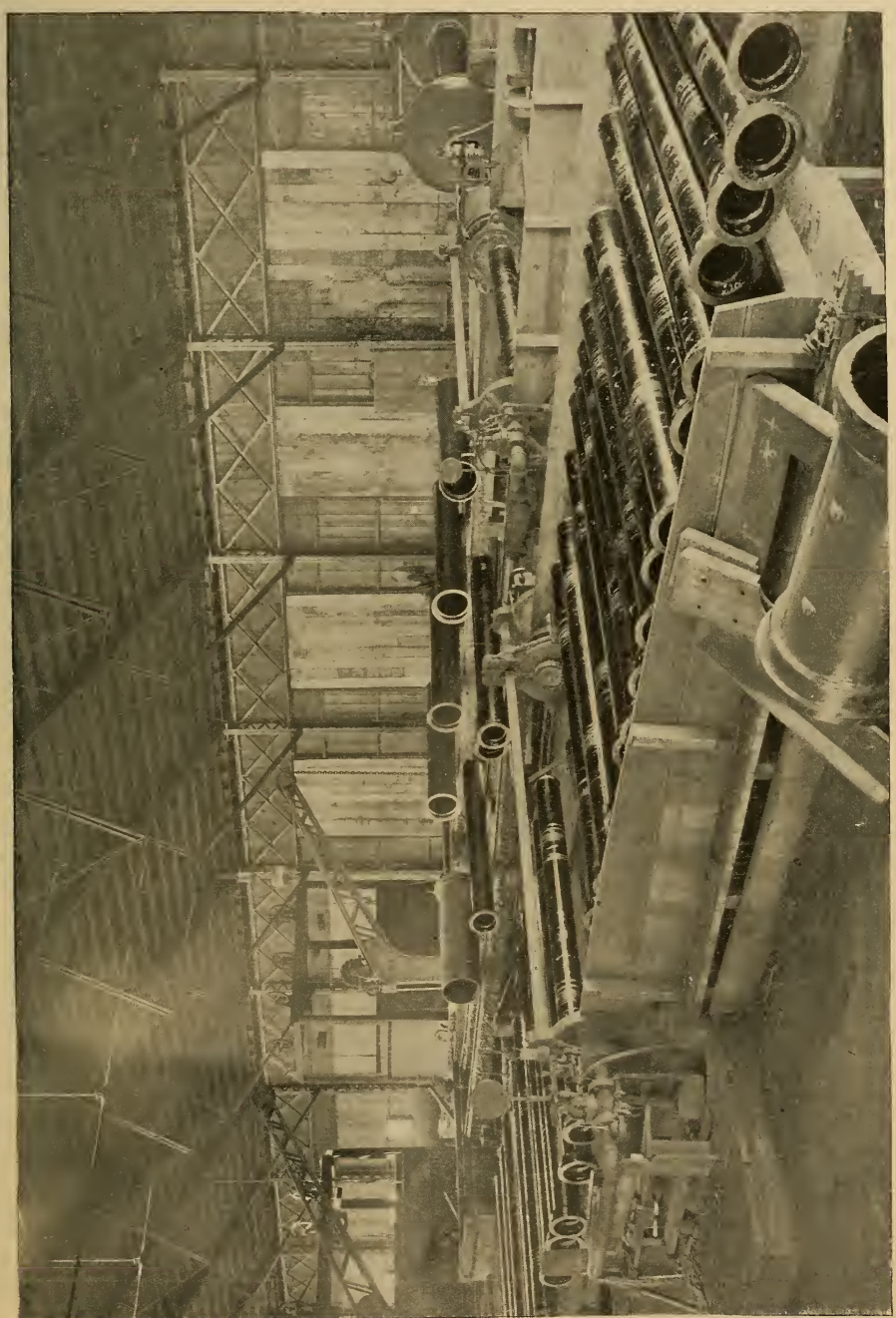
Fourth, the depth in the sockets in the bells must be right. The allowed variation is usually ¼ inch short to ½ inch long. It is important to note also that when the sockets are long they are not so long as to make the metal thin at the bottom by extending into the fillet joining the bell with the body of the pipe. In this way each bell is examined in turn by the inspector, keeping tally of good and bad pipes by the numbers cast on them.

Then the spigot-ends are examined the same way. They, too, must be truly round, of correct diameter inside and out, to enter sockets, and the metal should be of the same thickness within the allowed variation. It is necessary to repeat all the measurements at each end, as a pipe may be truly round at one end and oval in shape at the other, and a core may be truly centred at one end and oval at the other. The beads must not overrun prescribed diameters, and if they do in places, must be trimmed to correct size. Spigot ends require generally a freer use of the hammer than the bell, and a closer watch for blow holes, because, as a rule, this end is uppermost in the flask, and is apt to contain slag, cinder pockets and scoria. If the metal is inferior at the spigot end, it will often break under the blow of a two-pound hammer. If, however, the metal is good and sound, it is not considered necessary that the beads should be as clear in outline as the bells. As long as there is a distinct bead and it is trimmed clean to enter any socket freely, it should be accepted.

So much for the ends of pipes. The inside and outside surfaces have next to be looked over carefully. There are a number of defects to which pipes are subject. These may be enumerated as follows: Scabs: Lumps or patches of superfluous metal, due to defects in core or mould. Cold Shuts: Places where part of the metal has chilled before the adjacent metal has flowed over it; this makes a seam or weld in the casting. Sand Holes: Pockets of sand. Checking: Shrinkage cracks, found usually in the top of the casting, and due to cold shortness. Blow Holes: Spongy metal, due to froth and scoria in the iron. Gate Shrinks: Hollows leading from the gate into the body of the pipe. Core Cut, Mould Cut or Socket Cut: These are places where the mould has been cut away by the flow of melted iron. This is most objectionable in the socket, which is spoilt by it. It is bad anywhere if there is much of it, because the sand is in the body of the pipe. Cracked Cores: Places where the core has cracked in long lines, leaving sometimes ridges, sometimes seams along the body of the pipe. Crushed or Swelled Cores or Moulds: These produce ridges or rings on the pipes, and are due to failure of cores or moulds to retain their shapes. Facing Washed: Places where the lamp-black facing has either cut the sand or covered it in lumps on the surface of mould or core.

All these defects in the castings a skillful inspector must be on the watch for, and so skillful do the best men become that it is rare indeed that a defective pipe escapes their attention. The rejection of pipes for these causes is often made regardless of their ability to stand the hydrostatic pressure in the proving press. This is done, of course, because defects such as those noted above seriously affect the life or endurance of pipes.

When an inspector has finished his morning's work in the cleaning shed on the lines indicated above, his next duty is to go to the proving press and test the pipes which he has previously examined, and which have, in the meantime, received a coating of tar. In the proving press all pipes are tested under hydrostatic pressure, generally 200 lbs. or 300 lbs. per square inch. The process is as follows: Each pipe is run, in turn, into position between the two heads of the press, and one of these heads, which is really the piston of a hydraulic ram, moves forward and se-



VIEW OF TAR PITS AND PROVING PRESSES.

cures the pipe firmly at the ends against gaskets of hemp. The pipe is then filled with low pressure water and, when quite full, the 300-pound pressure from the accumulator is turned on, thus requiring a comparatively small flow of water at high pressure.

While the pipe is being fitted in place between the gaskets and until it has filled, and the pressure has reached the figures required, it is always desirable to stand out of harm's way. If the pipe bursts, water, and sometimes iron, fly freely. After the pressure is on, however, the inspector must walk the length of the pipe, strike it several sharp blows with a hammer, and look it over carefully to see that it does not leak either through blow holes or cracks. Pipes that stand the pressure without bursting often leak through blow holes, either slowly or in jets, and must be rejected for this cause. Plugging can not be allowed.

The last step in the process of inspection now follows in weighing the pipes. The weight of a casting has always been regarded as an important indication of the soundness or unsoundness of its internal structure, and in all the specifications for water pipe the standard weight for each size is specified and the allowed variation carefully stated. The inspector, therefore, always witnesses the weighing of the pipes to see that they are within the standard requirements. The correct weight is then marked on the pipe and the inspector checks the weight, pipe number and size of all pipe accepted or rejected, in his note book and those accepted are then ready for shipment by the manufacturer.

This statement presumes, however, that the physical tests required have proven satisfactory and as these physical tests are ordinarily made on the afternoon of the day before the pipes are proved in the press the work is generally completed at the scales. Of physical tests it is usual to require two kinds in specifications. The first of these is a direct tension test, in which the iron is required to show a tensile strength differing in different specifications from 14,000 to 18,000 lbs. per square inch, the second is a transverse test which has been adopted by the American Water Works Association. This test requires that a specimen bar, 2 inches by 1 inch in section, laid flat on points of support two feet apart, shall carry a centre load of 1900 lbs. and deflect 5-16 inch before breaking. The tensile test proves the strength of the iron, and the transverse test proves its toughness or resilience. As iron may be strong without being tough, or may be tough without being strong, the two tests supplement each other very well and can be used together with advantage.

The test pieces are generally cast in the presence of the inspector. It is usual to have the moulds for the test castings set up alongside the cupola, and at some time during the day the inspector in charge of the work steps into the foundry and asks the foreman to cast his test pieces. They are then immediately poured and the selection is thus made entirely at random. The appended tables show the results of a series of tests made last year on an excellent quality of foundry iron.

Tensile Tests.

Total number of tensile tests made	265
Highest tensile test	30,890 lbs.
Lowest tensile test in good test pieces	17,600 "
Average results from the best three	23,510 "

Transverse Tests of 2 Inch by 1 Inch Bars, Laid Flat, and Loaded at the Centre Between Supports 24 Inches Apart.

Total number of transverse tests made	310
Highest breaking load recorded	2,620 lbs.
Lowest breaking load recorded in good specimen	1,700 "
Greatest deflection	0.46 inches
Least deflection in good specimen	0.29 "
Average breaking load of best three	2,040 lbs.

In another foundry, under the same specifications, the following series of

results were obtained, representing also an excellent quality of foundry iron :

Tensile Tests.

Number of tensile tests made.	193
Highest tensile test recorded.	25,600 lbs.
Lowest tensile test recorded in good specimen.....	16,670 "
Average tensile test of the best three.....	20,750 "

Transverse Tests of 1 Inch Square Bars, Loaded at the Centre Between Supports 12 Inches Apart.

Number of transverse tests made.....	367
Highest breaking load recorded.....	2,850 lbs.
Lowest breaking load recorded in good specimen ..	1,900 "
Average breaking load of best three.....	2,290 "
Minimum deflection in good specimen	0.10 inches
Maximum deflection in good specimen	0.16 "

The specifications required four tests to be made at a time and the acceptance or rejection of the iron was to be based on the average of the best three out of four.

The percentage of rejections under skillful inspection, for both tests and surface inspection together, varies very much from day to day. In a foundry the unexpected is always happening. Sometimes the mixture of iron is not right. At other times the sand is not quite satisfactory. The condition of the sand varies somewhat with the weather, and requires different handling, depending upon the condition of the weather. There are occasions when an entire day's work will be spoiled in this way by some accident in the regimen of the foundry. On other days, and sometimes for days at a time, the pipes will nearly all be of a high standard. On an average, however, it is believed that something like one-third of the pipes cast in the pit will be condemned as unsalable for water mains for one cause or another by an inspector representing the purchaser. Quite a percentage of these can still be disposed of by the foundry for use as railroad and highway culverts.

To every large pipe foundry there are attached two subsidiary foundries for making special castings, such as tees, branches, reducers, bends, crosses and valves. These foundries are known respectively as the green sand foundry and the loam foundry. A picture of a large loam foundry attached to one of the greater pipe plants is given on page 22, but as neither of these subsidiary foundries differ materially from any ordinary foundry, the writer has not thought it worth while to describe them in this article, which is especially devoted to cast-iron water pipe.

FROM AN INSPECTOR'S NOTEBOOK.

By G. C. Henning.

AT the request of the editor of CASSIER'S MAGAZINE, the writer has put together a few scraps of his own experience of many years as an inspector of structural materials in various mills and shops, and in the field as well, on both sides of the Atlantic, and would emphasize, at the outset, that "Yankee" tricks are pretty well parallelled in England and on the European continent.

It was in 1874 when frequent visits to a shop caused the writer to wonder that blow holes in castings which were to be water and air-tight, should be plugged up by wrought-iron bolts. His remarks were resented sharply, and he was told that no shop could afford to replace such slightly defective castings, as the job was contract work and the inspector would not see it; moreover, the work, it was claimed, would be perfectly tight. It seemed reasonable that this might be so, but later experience proved that it was otherwise.

These castings were to be closed by covers with ground joints, and were to hold a certain air pressure for a definite time before they were to be accepted. The ground joint having been finished to the satisfaction of the artisan, air pressure was applied; but to his amazement the pressure fell rapidly. As he knew nothing about the plugged holes, he laid the cause of leakage to the joints; hence, the apparatus was disconnected, and the joints were still further ground. After the work and the tests had thus been repeated for five days, it was finally concluded that the trouble lay not in the joints, but elsewhere, and upon referring the difficulty to a higher authority, the plugged holes were brought to notice. After scraping off the paint, the man in charge caulked the ends of the plugs inside and out. The pressure could then be carried indefinitely, and the inspector passed the work.

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The labor in this case alone amounted to twice the sum that a new casting would have cost, and yet the troubles had but just begun. After putting the machine in operation, repeated application and removal of pressure caused the bolts to leak again, and the users then not only refused to pay the contractors, but charged all damages caused by the leaks to their account, and they were compelled to replace the machine by a perfect one or lose all future orders.

On another occasion, on a visit to a shipyard, a large passenger steamer was found on the stocks while its machinery was building in the shop. A gang of men was seen working on the sternpost of the vessel, some of them clamping and reaming the holes in hull plates and forged stern post, while others were driving rivets in the adjusted holes.

Beside the riveting gang stood a small rivet furnace, and in the fire were about five or six rivets, fourteen inches long, three inches of which length were in the fire. When the end of a rivet was hot it was put into place in a prepared hole and a slight tap of a hand hammer drove it entirely through the sternpost and plates. Then the end was quickly hammered and a head formed

in the countersunk hole. This finished the driving of these rivets, which were the only security against loss of rudder and stanchness of the steamer's stern.

Two sister ships were built like this at the same yard, and both arrived at their ports of destination in such leaky condition, after their first voyage, that it became necessary to caulk all seams and rivets before again putting them into regular service. One of these ships was wrenched to pieces on her first return trip, in a severe storm and sank, while the other has been constantly in need of repair ever since her launch.

In the forge of this shipyard the main shafts of these ships were being welded at the time, and one of them showed a gaping spot where the fagots had not been thoroughly united. To remedy this defect, by welding another bar in place after cutting out the defective spot and then drawing the shaft down to size under the hammer, a block of iron was laid into the defective part, heated to a welding heat and then driven down into place by the steam hammer. The undoubted cause of the defect was the burning of the fagot and the presence of slag ; but the smiths made no attempt to remove the burnt ends nor the slag which must have gathered under and upon the sides of the inserted block of iron. The result of such work upon the life of an engine shaft can readily be realized by all.

In other ship yards where bulb-iron and frames for ships are bent to templets, it will be frequently noticed that red-short iron and steel, particularly the former, will show many small cracks at the point of greatest curvature. These cracks are almost invariably signs of defective material ; but instead of using metal which will bend properly, perhaps costing a very small fraction of a cent per pound more, it is customary to place such defective parts in a small forge fire, bring the iron to what the smith would call a welding heat, and, having dusted a little borax or welding compound on the cracks, weld the cracks up.

Unfortunately very little objection is raised to such proceedings on the part of practical men. The accident to the steamer Paris gave further evidence of what contractors consider permissible. It was acknowledged at the time that five of the six columns of the starboard engine were patched. Can any one wonder that ocean passenger steamers occasionally disappear, without the slightest trace of the why and wherefore.

Boiler-makers, it is to be regretted, are fully as heedless as shipbuilders, and as the evidence of their wrong-doing is generally lost by the complete destruction, by explosion, of their work, they, only too often, take chances which we might well impute to criminals. In one case that came under the writer's personal notice the tube sheet of a return tubular boiler was cracked from tube hole to tube hole, at a point almost in the centre of the sheet. It was a second-hand boiler, bought in by a shop to be rehabilitated and again sold. To make good this serious defect, after all the tubes had been removed, a hole was drilled through the crack between the tube holes, and a plug screwed in ; then both ends were slightly upset and caulked, and the crack caulked as well. After refitting the tubes, the head appeared to be tight upon applying the hydraulic test. An intending purchaser examined the boiler, and asked the writer to point out the repairs, as it was known to be second-hand. Of course, on being shown the defect, that client refused to buy, and the narrator pocketed severe censure. Another, less careful purchaser, however, took the boiler and discovered the defect upon putting it in use, and the result was that all the supposed profit and more was swallowed up by repairs before a settlement was reached.

In another shop, a sheet that had been cut too short at one corner was to be used for the shell, so that this scant corner would become an inside lap of a double-riveted joint. As the boiler would have been delayed for a month by waiting for a new sheet, a novel expedient was adopted. As the outer row of rivet holes came so near to the edge as to cause bulging and

cracks while punching, the plate was cut off for the space of four rivets, so that the new edge of the plate coincided with the centre line of the outer row of rivets.

After these rivets had been driven, the missing part of the plate was replaced by red putty in such skillful manner that the inspector using his hand lamp on the inside was unable to detect it. Several months later, however, when the boiler became leaky, a renewed inspection at once exposed the fraud, as the putty had dropped off under the effect of steaming and working strains.

It may be said right here that there are a thousand ways of covering up defective work in boilers, which are of such common occurrence that it is hardly worth while referring to them. When holes have been punched so far wrong that they do not meet the corresponding ones, it is usual to insert screw-plugs and caulk their ends to make them tight, but if they are only slightly misplaced, a plug is what is called "welded in place;" that is, an attempt is made to weld a plug in the hole, by bringing the plate and plug to a very high heat and then hammering the spot very thoroughly. A new hole is then drilled in the correct place, as punching would again break the plug out. All the serious effects of heating a boiler plate locally are disregarded for the sake of a few dollars. Poorly driven rivets, or rivets which have been driven in poorly fitted sheets are commonly caulked and made tight, at least until the cold pressure test has been made; of course, all such rivets become leaky in a short while.

The above cited case of poorly sheared plate leads us directly to visit the shops of the steelmaker in order to inquire into his methods and find out why he should ship such work, knowing it to be defective, and often receiving his compensation before the plate is used. All the men in a rolling mill are paid by the ton; hence, output determines their weekly wages, and every nerve is strained to increase these as much as possible. No matter whether the orders have been filled and specifications met conscientiously or not, so long as the superintendent turns out the desired amount of product, he is the man who commands respect. Furthermore, as the profit to the manufacturer increases rapidly with the output, he looks primarily to quantity and not quality. Hence we see that, whichever view we take, all interests are toward hurrying, and all energies are bent toward quantity, and the buyer must look to his own resources in determining the quality of the material which he may buy.

Before steel had come into general use for structural purposes, most specifications contained a clause prohibiting the use of old rails in plates and shapes. These rails were always high in phosphorous and made the finished material non-homogeneous and often crystalline, but stronger. But as they were cheaper than other scrap-iron and muck bar, every mill used more or less. Two favorite methods of introducing them without the knowledge of the inspector were in common use. The first is a very easy one and was encouraged by the wording of some specifications. As all rolling was to be done during the presence of the inspector, and as he could not possibly be on duty twenty-four hours at a time, and rarely had any assistance, all preparatory work, such as making blooms and slabs, was done at night. The result was a most perfect looking lot of material for building up piles in the morning for the day's work. These slabs and blooms were, however, made largely or entirely of old rails, which lost their identity during rolling, and an examination on the part of the inspector the following morning would reveal nothing at all.

The second method was practiced by one of the largest mills, whose business was of such magnitude that a separate mill, located a few miles distant in another valley, was constantly engaged in making slabs and blooms, and used very large quantities of rails. Inspectors were not admitted to that mill on the ground that they had no business there, as finished shapes were not

turned out there. In fact only one or two inspectors or engineers knew of the existence of that mill, and the owners resented any allusion to their use of old rails by an outburst of virtuous indignation.

With the introduction of steel for rails and structural purposes, this deception has lost its importance, and others have replaced it. It has now almost become a matter of pride among manufacturers to work as close to the minimum specification requirements as possible. In many places manipulation of test-bars and testing machines has become the order of the day ; but it must be stated that in the foremost works, which have a real reputation for quality, irregularities of any kind are not tolerated.

Rolling mill men understand the heat treatment of steel so well that they can, by careful, legitimate means, produce a great variation of physical properties of the finished shapes, having previously determined the quality of the ingot by chemical or physical test, or by both. It is a well-known fact that softness or hardness, strength and ductility can be largely modified by application of higher or lower heat, by repeated heating and by rolling at various temperatures. An intelligent metallurgist will know his material from the stock, and then obtain final results by heat treatment. Selection of the test piece will also determine results, and if the first test is not quite satisfactory, a second one can be so chosen that it will fill all requirements.

It was formerly the rule to accept all steel on the results of tests of round rods, ¾-inch in diameter. When the first rod was weak, a second one could easily be produced by cold rolling or other treatment that would fill all the requirements. When, on the other hand, the material proved too high in tenacity or hardness, it could be readily tempered and modified. Again, in cutting test pieces from finished shapes, they can be so selected that when tested they will show results varying considerably. Thus a strip cut from the edge of a plate showed different results from those obtained with a strip taken from near the centre ; the opposite ends of a plate or shape also vary, because one may be from the top, while the other may be from the bottom of the original ingot.

Hence, if the quality of the steel is known in general, intelligent selection will provide test pieces which will fill all requirements, provided errors have not been committed in successive manipulations of the product. But the less troublesome method, which is resorted to by some steel works, is to cut duplicate coupons or test pieces from bars or shapes previously accepted and to submit them as representative of successive heats. Strict personal selection on the part of the inspector would prevent such practice.

Another method of obtaining desired results, which has been practiced and must be guarded against, is the wrong measurement taken by the operator in the testing room. It is habitual for inspectors to sit by and look on without making measurements and observations, merely recording the results as called out by the mill assistants. The mill men may know that the material will show lack of tenacity by previous tests. Then, in order to show greater strength than the material would actually have per unit section, the measurements of section of test piece are called out smaller than they really are. Now, the machine showing actual loads applied to a test piece which is larger than the recorded dimensions, the results calculated per unit area will also be larger and the material will be accepted as fulfilling the specifications. On the other hand, it may be known that the material is lacking in ductility, as measured by ultimate elongation after rupture. The original standard length, marked by centre punches or spacing punch, is therefore made to measure more than it should be in fact, and, hence, a greater length of specimen being strained than is supposed, the results will be higher than if correct length had been used.

Still another method of making results satisfactory, is the jockeying of the testing machine, or by calling off

incorrect results. The first is done by the operator pulling on the connecting link joining the last lever to the other system, thereby producing a greater apparent load, as read by the running balance weight. Then, too, as the operator usually stands between the inspector and the weighing beam, he is able to read off the desired figure after rupture has occurred and, then rapidly placing the weight at that point on the beam by a twirl of the hand, prevent detection of the trick.

In some of the bridge shops anything goes that sticks together, while in others the principal aim is to turn out only the best and correct work. Still, some that claim to do the latter do not hesitate to try to foist on the engineer poor work. In one case, where the specifications required the reaming of all holes which would not allow a cold rivet to pass through them, the superintendent calmly ordered holes 1 inch in diameter to be punched for ¾-inch rivets, using a die under the punch of 1 1-16 inches diameter. Although such large holes materially weakened the structure, the contractors declared that it was all right, and even insisted that such practice was usual, although no other work going through the shops at the same time had holes punched more than ⅛-inch larger than the diameter of the rivet.

A very prominent manufacturer once took the writer to task severely for requiring rectification of defective work, which would cause delay in the shops. He did this on the ground that he was under bonds to complete the work at a certain time, and could not do it if he were required to turn out the work in accordance with the specifications. He emphasized that it would reduce profits, and when you touched his pocket you touched his heart, which he would not tolerate. He became quite eloquent and wrothy on this point, and explained that the only pleasure he took in the work of his shop was in the gain it ultimately brought to him.

At the same shops they were obtaining their first experience in working steel and driving steel rivets, and, of course, had as much to learn and more to unlearn than any other similar works, as most precise methods and rules had been established as to how everything should be done, hence all work had become "stereotyped." These methods had been so thoroughly engrafted throughout the shops that it was most difficult to introduce new ones, such as avoiding cold hammering, drifting and driving rivets cold. The latter caused so much trouble by loose rivets and consequent repairs that they quietly decided to use iron rivets instead of steel, in spite of the specification requirements and contract, believing and trusting that the inspector would not detect the fraud, or if he did, could be made to believe that iron was actually better than steel for the purpose; that the work would suffer less from cutting out loose and defective rivets, etc. It never occurred to the superintendent that the easiest, cheapest and only correct remedy was to change the method of heating and driving the rivets.

When the inspectors discovered the deception, they were coolly informed that it was none of their business, as iron rivets did not impair the strength of the work, and that steel rivets could not be driven to be perfectly tight. In fact, the contractors would not desist in the use of iron rivets until compelled to do so by the chief engineer, to whom the matter was referred, and who also insisted upon having several thousand iron rivets replaced by steel, in work which had been driven and finished, after the inspectors had objected.

At these shops the usual answer to a request for a change of method was the dictum, "It can't be done." Although drifting rivet holes to make them match was forbidden, it was the usual custom to drive three or more drift-pins through the connecting rivet holes in chord angles and adjoined lattice bars, the holes being so much mismatched that reamers could not be entered in them. When bars or angles had been cut off too short, they were taken into the forge and drawn out after heating, so as to be lengthened

a little by swaging ; when slight cracks were developed a little putty or paint, judiciously applied, would conceal the defect, and crooked, built-up sections, would be straightened by merely bending them permanently until the kinks disappeared. When such distortion occurs in a finished structure, every bridge builder will insist that the defect must be remedied at once by substituting a new member, but when it happens in the shop "it would be an outrage to ask for a new piece, because a little cold straightening will make it all right."

Caulking loose rivets is a matter of course, and it was always the "ruination of good work to cut out loose rivets." As for taking a finishing cut over squared abutting ends, that was styled "polishing" the work, and the coarsest kind of a roughing cut was declared amply good and accurate, even though strips of card board could be inserted in grooves between the abutted ends.

In the machine shop the inspectors' mark of rejection placed on the ends of pins was turned off, and the pins thus changed submitted for a second inspection. Discovery of such proceeding caused the rejection stamp to be put on the body of the pin, and this raised a howl of indignation, because that "would prevent this defective material from being used in work for other engineers," who were not so particular, or who accepted it without inspection under the assumption that no contractor could take the responsibility of delivering anything but perfect work.

In forged work particularly much defective work is covered up, and it takes an expert to detect it in most cases. When, for instance, material is improperly heated, or the weld is filled with dirt or slag, defective welds will be sure to result, and these are covered up by reheating and the use of the hand hammer, or even by covering them by welding on new, thin pieces. When, in the case of iron eye-bars, the material in the neck of the bars has been allowed to waste away, small blocks of iron are sometimes placed on the middle of the bar at the weakened spot, and, after reheating, are driven into the bars under the steam hammer to spread the bars to their required dimensions.

In cases where there are bad welds, or cinder seams or blisters, in the heads of eye-bars, made apparent by boring the pin hole, rings of metal are welded into the holes and are then rebored to correct size. This would, of course, produce a perfectly smooth pin hole, covering up all traces of defective welds between the piling of an eye-bar head, but would only make the eye-bar still more defective. Nevertheless, such methods have been repeatedly followed under the impression that the inspector would not notice the deception.

These are a few of the abnormal happenings in shops of different kinds, and it would lead too far to enumerate others, except just two which are of common occurrence in the field. All pedestals supporting bridge ends are supposed to be secured to the masonry piers by means of anchor bolts, to avoid possible shifting on, or lifting of the bridge from, the piers. It has occurred that the erecting gang, not having tools for drilling on hand, merely inserted, in place of long anchor bolts, short studs with nuts on the upper ends, so as to give the appearance of having properly secured the bridge. The other case was the insertion of two very short rivets, end to end, in a hole, as rivets of proper length were not on hand. As the men moved from span to span, these matters would of course be forgotten, and only accidents reveal such defects. What excuse can be offered for such shortcomings in view of the fact that they recur ?

What principle of policy or of morality can be evolved on which such methods are based, with the purpose of ultimate benefit to the proprietors of such establishments ? And moreover, can an engineer who has had to contend with all of these practices, approach manufacturers without some slight misgivings as to intentions, or with confidence in their honesty of purpose, integrity and fairness ?

A FRENCH SIGNALLING STATION IN 1794.

TELEGRAPHY AS IT USED TO BE.

By G'r. Lodian.

G'R. LODIAN has, for a number of years, contributed extensively to various engineering periodicals both in England and in America, occupying himself chiefly with railroad topics. As an enthusiastic tourist his opportunities for collecting data of general interest have been many, and some of these, gathered during a ramble through Southern France, have been made the basis of this article.

PUTTING UP A MILITARY TELEGRAPH LINE.

"CONDÉ est repris!" "Condé is retaken! Condé will be restored to the Republic! Surrender to take place this morning at 6!" Carnot, grandfather of the late French President, had mounted the tribune in the National Convention and read a dispatch containing the above words. It was the 13th fructidor, 101 years ago. That dispatch was the first telegraphic national message of which the old Moniteur gives any record, whence are taken the preceding particulars.

At that time, struggling republican France was at war with nearly the whole of Europe, whipping her foes right and left. Condé was a town besieged by the Republican troops and it had just been retaken by them when the historic message above recorded was read to the Convention at Paris. From that moment aerial telegraphy was a triumph for France, and it continued to grow over the land for half a century until 1844.

It was on the 22d of March, 1792, that a young man, named Claude Chappe, presented himself at the bar of the National Assembly at Paris. He carried with him a secret vocabulary composed of 9999 words, represented by numbers, and destined to be transmitted by a system of visual telegraphy, aided by a machine which would signal from station to station. The examination of the project was at once put into the hands of a corps of investigation, who decided on its adoption and the Convention voted the necessary means for conducting a series of trials. The delegate Romme, mounting the tribune, thus announced to the Convention the particulars of Chappe's invention:

"The Citizen Chappe offers an ingenious means of aerial telegraphy by displaying a few characters, simple as the straight lines of which they are composed, very distinct one from the other, of rapid movement, and visible at long distances. At this first part of his procedure he is aided by a stenograph used in diplomatic correspondence. The employes working the Chappe machine cannot betray the secret of the messages entrusted to them because they will be ignorant of the stenographic value of the signals. The news of the taking of Bruxelles by the French troops was transmitted from that city over the Chappe apparatus to Paris in twenty-five minutes. Your committee recommend the adoption of the system of the Citizen Chappe."

In the early spring of three years ago, during a holiday ramble of several hundred miles afoot right through

France and over the lonely Pyrenees into Spain, the long walk occupying five weeks continuously, the writer saw numerous vestiges of what was once the greatest system of aerial telegraphy in existence. These were the remains of the solitary towers, usually erected on the most prominent hillocks in the district, and which, up to 1844, formed the telegraphic system of France. In that year there were 535 stations, representing over 5000 kilometers of communication. In that year also the electric telegraph was successfully experimented with and the fate of aerial telegraphy was sealed. Wires were run up all over northern France, but the lines were exclusively reserved for the use of the government.

Not until the end of 1850 were private individuals allowed to send messages by telegraph, and then only (in the words of the law) "after vigorous constatation (proof) of their identity." The tariff then was 3 francs, or 60 cents, for 20 words and "the secrecy of the dispatches was declared inviolable." A few months later the first submarine cable was laid, between Calais and Dover, and the first regular message from England was that sent to Louis Bonaparte, then president of the Republic.

Claude Chappe was born at Brulon, in the Sarthe Department, in 1763. His studies were concluded at the little seminary of La Flèche, near Rouen. His brothers were educated at a different college, some distance

CHAPPE'S FIRST APPARATUS, 1792.

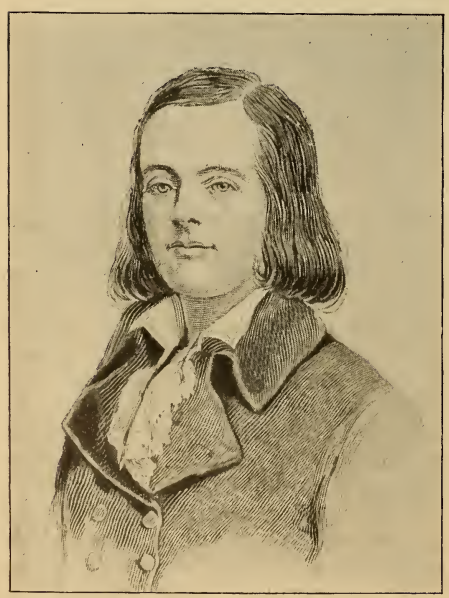
A LONELY POST IN THE HILLS, 1795.

from, but in view of, the institution where Claude was and it is on record how, in order to communicate with them, he arranged a series of signals from his dormitory window. These being understood, were answered according to a code. That was evidently the foundation of Chappe's invention. Some say that this story is fictitious, but it is a decidedly pretty and natural one.

His study of the sciences was such that at the age of 20 years he "pleased an enemy"—if he had one to please. In other words, he wrote a book. These mémoires of his have been pronounced "very remarkable," although the student of physics who may consult them at certain great libraries will probably think otherwise. Chappe put up his first telegraphic machine at Belleville, the Bowery of Paris, but located on high ground. There were "toughs" in those days, and it was these who destroyed the Chappe apparatus, so that the inventor had to seek police protection for future experiments. Chappe was the first man to receive the title of engineer-telegraphist, and he received the pay of a lieutenant of engineers as in the service of the State. Delirious, through cancer of the ear, he committed suicide by throwing himself down a well in 1805.

OPTICAL TELEGRAPHY.

As with electrical telegraphy, so with aerial telegraphy, the early attempts were legion. A century before Chappe was born, a scientific attempt at long-distance telegraphy was made by the savant Amontons. The author Fontenelle has written of these experiments. He states that the apparatus was a clever contrivance, permitting of the transmission of a message from Paris across the Alps to Rome in the then incredibly brief time of three hours, and this without anybody knowing the nature of the message between the Italian and French capitals.



CHAPPE, THE INVENTOR OF AERIAL TELEGRAPHY, 1792.

The procedure consisted in placing at several consecutive spots men, who, having perceived through long-distance telescopes certain signals, made at one post, transmitted such signals to the next post, and so on from post to post, and these different signals were so many letters of an alphabet of secret ciphers. The key to these was known only to the parties interested at Paris and at the city a thousand miles away. The maximum range of the telescope constituted the distance between the different posts, the fewer of which, the better for rapid transmission. Some experiments were successfully made over a little stretch of country, but the vice-consumed functionaries of the time pronounced the Amontons project "impracticable," and the discouraged inventor abandoned his idea.

Cæsar, in his commentaries, relates how, during the invasion of Gaul, the inhabitants gave warning of his approach by burning fires at night. These signals were called "huchées." In the daytime the old Gauls resorted to cries. Thus, a number of men, stationed at certain intervals apart over a

long stretch of country, would shout their warnings from one to the other. This species of mouth-to-mouth telegraphy answered so well and the dispatches traveled so quickly that Cæsar states how, between the rising and setting of the sun, the natives could send a verbal message a distance of over 50 leagues. A league is commonly supposed to represent three miles, more or less (except the decimal league, which is 10 kilometres, equal to about 6¼ miles), so that the mouth telegraphy of the old Franks covered the respectable distance of about 150 miles a day. Bonfires and the *houppes* (from *huppa*, to cry out) constituted the telegraphy of the ancients and moderns until 1792. In fact, up to the present day, in many parts of America and England, there is still preserved the long-distance French shout of *houppe-là*, being more powerfully expressive than the English equivalent, *oh-there!*

The old telegraph stations of France are interesting relics of the past and, where they have been allowed to remain, form a feature of the landscape. They were of two kinds, the square towers and the round towers. They consisted of two stories, and the index signals, of wood or light iron, were mounted at the top of a pole on the roof. A ladder ran up this pole, so that the signals might be reached and moved by hand. The telegraphers were provided with telescopes and there was always somebody on watch on the roof to note sig-

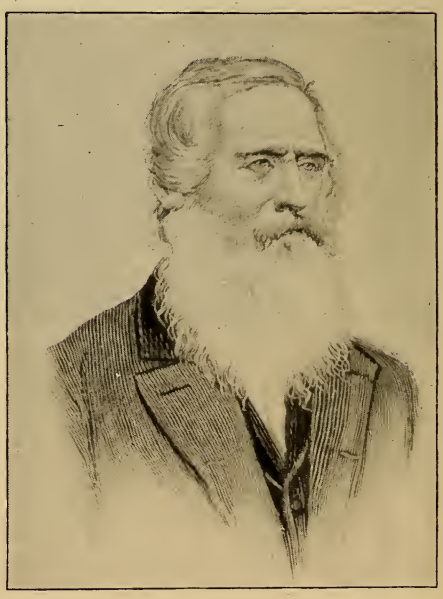
SIGNALLING BY THE ANCIENT GAULS.

A SEMAPHORE STATION ON A CRIMEAN BATTLE FIELD IN 1854.

nals made at the neighbouring stations. The progress of a message at night was naturally slower than the day transmission. The words were fewer at night also, because the small lanterns affixed to the indexes could occupy only a certain number of positions without being extinguished.

The first Bonaparte extended the line of these stations to Milan, then to Mayence, in Germany. They went no farther. Soon the French armies began to retreat to the land from which they came, and as they retired they fired their telegraph posts to prevent the enemy from using them.

A not well-read writer has stated that Alexander's quickest means of sending messages was by fast horses and that Napoleon, two milleniums later, was no better off. This informant, like millions to-day, was ignorant of aerial telegraphy's half century of existence.



SAM. F. B. MORSE, THE INVENTOR OF THE ELECTRIC TELEGRAPH, 1837.

WATER-WORKS STANDPIPES.

By Wynkoop Kiersted.

THE standpipe, as a part of a system of water-works is usually the attachment of that particular system which requires the use of pumping engines to deliver water to the consumers.

As originally designed, the standpipe performed the part of a pressure regulator or equalizer to the system of water-works to which it was attached by maintaining an approximately uniform load and strain upon the pumps and mains. It was usually constructed of small diameter, enclosed within a masonry tower to protect it from the elements and exposed to few, if any, influences extraneous to the operation of the system as a whole.

The enclosing tower was frequently made so imposing in point of architectural beauty as to be considered one of the structural attractions of a city. However, as experience in the operation of water-works accumulated it demonstrated that various mechanical devices, easily controlled and regulated, could be made to satisfactorily perform the function of a standpipe; consequently, these ornamental structures are seldom seen in connection with recently constructed water-works systems in the United States.

The standpipe of to-day is usually of large diameter, ten feet and upwards, and of considerable height, consisting of a plain cylinder of iron or steel, with few, if any, ornamental details, and is intended to fulfill the part of a storage reservoir even more than that of a pressure regulator. In fact, as it is located with reference to the pumping machinery in many systems of water-works, it affords no protection to the machinery from concussion due to water hammer.

Such structures have been considered highly essential to water-works in small towns in sections of the country having available no natural elevations of sufficient height for distributing and storage reservoirs of earth, in order to avoid the necessity of continuous operation of pumping machinery. The available storage capacity of these standpipes is small, still the amount of water advantageously stored has generally been found sufficient to supply the night consumption of small towns, thus avoiding the expense of night attendance, and to afford some fire protection during the interval between an alarm of fire and the time when the pumping engine can be brought into use for fire service by direct pressure. Usually standpipes afford a satisfactory pressure for domestic service and are so connected with the pipe system as to be readily cut off from it in an emergency demanding a high pressure.

Ordinarily not more than one-half or one-third of the stored water is really serviceable and valuable; therefore, it might appear as though a tank of sufficient size and so elevated as to render available the entire volume of

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stored water would be a more consistent arrangement than the ordinary standpipe. But, because of the simplicity of design and the economy of construction, these simple tubes of iron or steel have been more popular and more generally used for the storage of water in level districts than have tanks when elevated either on trestles or on masonry towers.

The large number of these metal structures that have been built bespeaks their popularity. But however strong may be the arguments in favor of their utility and economy in the operation of water-works in small towns on level ground, they lose much, if not all, of their force when advanced in favor of a similar arrangement for large towns or a moderate-sized city with similar topographical surroundings; for, usually it is not feasible in point of expense to provide an amount of storage in a structure of this kind that will be found of much practical value. Nevertheless, a few cities of 30,000 inhabitants or more have thought it necessary to connect with the mains of the water-works a huge iron tank 25 or more feet in diameter and from 100 to 150 feet high. Such a tank is of unnecessarily large proportions for use as a pressure regulator, and is too small as a storage tank to avoid an almost continuous use of the pumping machinery. Its chief advantage apparently consists in providing a small reservoir for the storage of water when the rate of water consumption is less than that at which the water is delivered by the pumps or in supplying from this small reservoir the deficiency of water when the rate of consumption is greater than that of pumping, thereby enabling the pumps to be operated at an approximately uniform rate of speed.

Occasionally there is constructed a combination stand pipe, composed of an outside shell of metal, of sufficient height to provide a pressure upon the mains suitable for domestic service, and an inner shell, concentric with the first, but of such additional height as to provide a suitable fire pressure. This arrangement necessitates the connecting or disconnecting with the mains of one or the other of these standpipes at every change from a domestic to a fire pressure, or *vice versa*. Whatever may have been the special demand for a structure of this kind in cities where it has been erected, it is not one of general adaptability, for, wherever dependence for fire service rests upon the pumping engines of the water-works, that service can be more promptly and quite as safely provided by direct pressure from the engines as by any standpipe arrangement designed to perform a dual service.

In 1889 there was published in the Selected Papers of the Rensselaer Society of Engineers, of Troy, N. Y., a short paper on standpipes, written by the author of this article. It presented some formulæ and data for the design of standpipes composed of iron plates of rather an inferior quality; and discussed the subject of bending and collapsing strains to which the standpipe, as ordinarily constructed, is subjected by wind pressure. Since that date the use of plate steel has almost superseded that of plate iron in standpipe construction. Although the question of adaptation of steel for work of this kind has been quite extensively discussed the writer ventures to add a word or two upon it in order to cover the scope intended to be covered at the time the paper alluded to was written.

Indeed, the subject is even now worthy of more than a passing interest because of the failure during recent years of so many standpipes. The failure of these structures, which are high and weighty and subjected to intense strains when full of water, usually inflicts much damage upon adjacent property and seriously menaces life. Consequently, when of frequent occurrence, it must very naturally arouse feelings of suspicion and apprehension on the part of many communities among whom the standpipe occupies a conspicuous place in the busy or prominent part of the town, as it cannot be considered that very many of the standpipes which are intact to-day are of any better construc-

tion or composed of any better material, or are more closely scrutinized for defects, or any more carefully operated, or any more exempt from the combination of causes which have effected the downfall and destruction of some of these structures than were most of those which have failed. Some of the failures show clearly that the metal which composed some, at least, of the wrecked standpipes was unsuited to this class of structures, its chemical composition and method of manufacture having been such as to render it crystalline, non-homogeneous and brittle,—a class of material but poorly adapted, especially in thick plates, to withstand the internal strains, shocks and enormous water pressures to which standpipes are subjected under the ordinary conditions of service.

One of the most essential qualifications of a metal suitable for the construction of stand pipes is ductility, a qualification which is the usual accompaniment of a comparatively low tensile strength, and which should be quite as much a desideratum in the selection of plate metal for a standpipe as it is for a steam boiler ; in fact, in most particulars the specifications for both as to the quality of plates and character of construction should be almost identical.

" Tank steel," a material often showing, under test, a high tensile strength, is a most treacherous one to use in a standpipe, inasmuch as it lacks uniformity in chemical composition and ductility ; yet in numerous instances no provision is made either in the specification or in the inspection to prevent the use of it. A specification may require steel plates of a certain thickness and a tensile strength of 60,000 lbs. per square inch (and so stamped on the plate), without any provision for skilled inspection ; or it may define the characteristics of a desirable grade of metal and yet require or enforce no inspection to insure the specifications being properly complied with. Of course, under such circumstances there is, in many instances, ample opportunity of introducing inferior metal. To what extent this is done, with a door so widely ajar, one may conjecture when considering that a standpipe built of tank steel will cost less than one of mild steel or boiler plate. To insure a proper quality of metal it is not only necessary to specify the grade, but also to require certain physical tests and a skilled inspection at the shop.

In the paper heretofore alluded to on iron standpipes, those data on the diameter of rivets, thickness of plates, pitch of rivets, lap of joints, etc., are applicable to steel standpipes with joints riveted with steel rivets. While it is not necessary to repeat here those data, they may be rendered more complete by adding the following respecting treble riveting, a class of construction occasionally used in large standpipes :

Let d = diameter of rivet.
t = thickness of plate.
c = pitch of rivets.
l = lap of joints.

From foreign experiments it has been deduced that for thick plates in treble and quadruple riveting, $d = 1.6\ t$ nearly, with maximum diameter of rivet $1\frac{1}{8}$ to $1\frac{3}{16}$ inches ; for plates from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch thick, treble rivited, $c = 8\ t$; for plates from $\frac{3}{4}$ of an inch to 1 inch thick, treble riveted, $c = 6\ t$. For the best designed lap joints of steel plate the strength of the single riveted lap joint is 55 to 64 per cent. of the solid plate, that of a double riveted lap joint 65 to 75 per cent., and that of treble and quadruple riveted joint 75 to 80 per cent. of the solid plate.

From these data of joint efficiency, and with an average tensile strength of good mild steel of 60,000 lbs. per square inch, assuming that a minimum tensile strength should not be under 55,000 lbs., and a maximum not above 65,000 lbs. per square inch, a simple practical formula may be devised for determining the thickness of steel plate from the general formula for pressure in a cylindrical body a unit in height, namely, $2\ t\ T = p\ d$, in which,

t = thickness of the steel plate.

T = ultimate tensile strength per square inch, 60,000 lbs.

p = pressure of water per sq. in.

$$\text{or } \frac{H \times 62.5}{144}.$$

Let d = diameter of standpipe in inches = $D \times 12$.

H = height of standpipe in feet.

D = diameter of standpipe in feet.

S = safety factor = 4.

E = joint efficiency.

Then,

$$t = \frac{H \times 62.5 \times D \times 12 \times 4}{2 \times 144 \times 60{,}000 \times E} \text{ or}$$

$$t = \frac{H\,D}{5760\,E}$$

which formula, for single-riveted lap joints of steel, with $E = 0.6$, becomes $t = .00029\ H.\ D.$ For double-riveted lap joints of steel, with $E = 0.7$, the formula becomes $t = .00025\ H.\ D.$ For treble-riveted lap joints of steel, in thick plates, with $E = 0.7$, it becomes $t = .00025\ H.\ D.$ For treble-riveted lap joints of steel in thin plates, with $E = 0.75$, it becomes $t = .000232\ H.\ D.$

Theoretically, the thickness of the plate metal to withstand the static water pressure should be zero at the top of the standpipe and increase uniformly with the pressure to the bottom; but, in practice, the thickness of the metal is made to vary by sixteenths or thirty-seconds of an inch, with a certain minimum thickness of metal for the top sections, which is fixed by considerations of wind pressure, waste by corrosion and other considerations of a purely practical nature.

The foundation of a standpipe should be of heavy, well-bonded masonry, of a broad bearing and of sufficient weight to resist the overturning force of the heaviest winds blowing against the pipe when empty. These strains are transferred from the standpipe to the foundation by heavy anchor bolts passing through the foundation, attached to heavy anchor plates beneath the foundation and to brackets, preferably of wrought iron or steel, riveted to the shell of the standpipe. A determination of the strength of these details simply requires an application of the ordinary rules of mechanics for structures of this kind under the action of external forces.

The powerful effect of the wind upon an empty standpipe tends to overthrow the structure, to buckle the plates on the leeward side and to collapse the rings of the upper portion on the windward side. To resist the overturning effect, the standpipe and the foundation are supposed to act as one structure; therefore the weight and spread of the foundation is made sufficient to prevent any unusual yielding, either of the structure as a whole or of the supporting earth. The buckling strains on the leeward side of a standpipe are amply resisted when the thickness of metal is proportioned by the above rules for a static water pressure in standpipes of ordinary height and ten or more feet in diameter.

The minimum thickness of plates in a standpipe to avoid collapse on the windward side should be, for various diameters, about as follows:

For diam.	10 to 13 ft.,	a thickness	not	less	than 3-16″
" "	14 to 17 "	"	"	"	7-32″
" "	18 to 25 "	"	"	"	¼″
" "	26 to 30 "	"	"	"	5/16″
" "	40 "	"	"	"	7-16″

Available statistics of standpipe accidents and failures record a few failures by a collapse of the upper rings of certain standpipes which may be of interest in connection with the above table. At Victoria, Texas, a standpipe, 16 feet in diameter and 100 feet high, composed of rings of wrought iron, ½ inch in thickness for the first 70 feet and 5/16 of an inch for the remaining 30 feet, collapsed when the standpipe was empty, as the result of wind pressure caused by a hurricane estimated to have been blowing at the rate of from about 80 to 85 miles an hour.

At Kankakee, Ill., a standpipe, 20 feet in diameter and 124 feet high, was composed of metal having a thickness of ⅛ inch for the top 20 feet, and varying to 1 1/16 inch at the bottom. The pipe, being empty and exposed to a severe wind, blowing, it was estimated, at the rate of 60 or more miles an hour, collapsed at the top section and then overturned because of defective foundation and anchorage.

At Asheville, N. C., a steel tank, 45 feet in diameter, and 60 feet high, collapsed in the upper 20 feet of its height, which section was composed of ¼-inch plate.

At Plattsmouth, Neb., a standpipe, 25 feet in diameter, and 80 feet high, collapsed in the upper 40 feet of its height, in which the thickness of metal varied from $\frac{9}{32}$ to $\frac{3}{16}$ of an inch. In this failure the wind force, augmented in its effects by the vibrations of the structure, in all probability caused the upper and thin section of the standpipe to collapse; and, as this section collapsed, some of the heavier plates below were carried inward, which, of themselves, were probably heavy enough to withstand the shock of the wind alone. At East Providence, R. I., a steel standpipe, 40 feet in diameter, and 125 feet high, collapsed in the upper 35 feet of its height, where the plates were ⅜ and $\frac{5}{16}$ of an inch in thickness.

By referring to the table of minimum thickness, as above given, it will be noticed that in the failure of standpipes by collapsing, as just noted, the thicknesses of plates in the upper sections are somewhat less than those stated in the table. It might, therefore, be inferred that the thicknesses in the table are not much, if at all, in excess of what they should be, considering the fact that any standpipe is liable to exposure when empty, to wind storms quite as severe as those which caused the collapse of the structures which have failed.

In a state of emptiness, there is a certain amount of elasticity to a standpipe that admits of vibrations even though the foundation anchorage be secure; besides, it is impracticable in most instances to prevent a slight yielding of a standpipe on its foundation, particularly where the bearing surface is no greater than the external diameter of the shell, and, even though this yielding be slight, it admits of long swinging vibrations at the top of a lofty structure. For instance, should a standpipe, 12 feet in diameter, and 100 feet high, raise ¼ inch from the foundation, on one point of its base, it would admit of a swing at the top of about 2 inches from the vertical, and a rise of 1 inch would admit of about 8 inches swing. Such vibrations, in a high wind, may add considerably to the force tending to collapse the upper portion of the shell of a standpipe. Extension anchorage brackets, by the bracing laterally which they afford, add to the stability of a structure of this kind and tend to prevent vibrations. The mere ballasting of a standpipe with water is the surest and safest way of preventing dangerous vibrations.

Another element of danger to which plain standpipes are exposed is found in the ice which, at times, forms within them. Many failures of standpipes have been thought to be due to this cause. In these instances the cause of failure has been attributed to excessive strains produced by the expansion of water in a confined place at the moment of congealation, or to the fall of a heavy mass of ice detached by thawing from its supports when the water in the standpipe was low. It is difficult, indeed, to arrive at satisfactory conclusions regarding the precise nature of the conditions and causes combining to effect the destruction of a standpipe under such circumstances, but it is perfectly evident that heavy bodies of ice in a standpipe are a cause for apprehension.

A body of ice about the interior of the standpipe shell, obstructed in its movements by numerous rivet heads, joints and other inequalities, alternately thawing and freezing at surfaces of contact with the shell must cause many intense local strains, which may result in a progressive distortion at any section and a rupture of a joint, or it may, by a sudden shifting, strike a blow of intense power at some particular point. Serious pressure and concussion must follow the sudden yielding under pump action of a horizontal layer of heavy ice.

It is worthy of note that in several instances of failure noted the water supply was from a surface source. The water probably entered the standpipe or storage tank at a temperature but little above the freezing point, thus affording a favorable condition for the

formation of a heavy body of ice within the standpipe at seasons of unusually low temperature. The disastrous consequences of ice formation cannot be held to be illustrative of a danger prevailing in all towns subject to equally low temperatures, for, in numerous instances, the water supply is from the ground and enters the standpipe at a temperature considerably above the freezing point, which circumstance, together with the well-known property of water to retain heat, the continuous circulation of particles of water as the result of variable temperature and the frequent refilling of the limited storage space of a standpipe causes the diminution to a marked extent of the danger of excessive ice formations.

However, when large storage capacity is provided in a standpipe, or when the storage is intended for an emergency only, thereby admitting of considerable periods of rest, or when the entering water is at a low temperature and receives but limited circulation, there are dangers of an accumulation of ice during severe winter weather so heavy as to apparently render advisable the protection of the standpipe in part or in whole from direct exposure. It would seem as though in most instances this could be satisfactorily accomplished only by an enclosing and self-sustaining tower sufficiently removed from the standpipe to admit of workmen repairing any leaks or defects that may develop. Such a method of protection involves much expense, but it seems the only positive method of attaining the desired end.

But to return to the discussion commenced in the first part of this article regarding the adaptability of the standpipe to useful service in connection with a system of water-works, there are three cases which perhaps embody most of the conditions which seemingly favor the use of this structure :

1. When the available water supply is somewhat less than the occasional maximum rate of water consumption. Anyone familiar with the operation of water-works knows that the hourly and daily rates of water consumption fluctuate between comparatively wide limits. Should the yield of water from the source of supply be somewhat less than the maximum rates of consumption at certain periods, as is sometimes the case with a supply taken from the ground, there would be fixed a limit of available water supply independent of the occasional rates of consumption, which, if exceeded, would cause an unusual, and perhaps, an inconvenient reduction of pressure within the distribution pipes of the water-works. But if a small amount of storage be provided water can then be delivered at a rate equal to or above an average rate of consumption, and any amount of water in excess of that required to supply the demands at low rates of consumption can be stored, to be drawn upon at periods of high rates of consumption, exceeding the available supply. In various instances a standpipe has been provided to store the surplus water for delivery at seasons of heavy drought, thereby serving to delay for a time expenditures in developing a supply of water equal to all demands.

Without other provision for emergencies than the standpipe storage and the available water supply a town must be but poorly equipped for efficient fire protection and under such conditions it is, in all probability, a result rather of fortuitous circumstances than of good management that a fire does not, at some time, reach uncontrollable proportions. In view of efficient service, it were better to have added to the system of water-works a storage reservoir at the pumping station, or, failing to have sufficient funds for this purpose, to have expended the money invested in a standpipe in developing a greater supply of water and in building this reservoir for a reserve supply of water for those brief periods of excessive consumption which occasionally arise. In that event the water would be delivered by direct pressure. It is not apparent that the end sought to be attained, as stated in the beginning of this case, is sufficient ground to justify expenditures of money in a standpipe and thereby forfeiting, to a degree, the security of

a good fire service, which may be had by applying the money in other directions.

2. When it is desired to operate the pumping machinery for but a portion of each day. This case is applicable only to towns and small cities which desire to cease work for a portion of each day in order to have an opportunity to make minor repairs to the machinery and to avoid the necessity of night attendance. With these ends in view a standpipe is erected. The available storage of the standpipe is usually too insignificant to avoid the necessity of duplicate or reserve machinery having almost as great capacity as would be necessary in machinery performing only a direct pressure service.

In numerous instances, in towns of an approximately level site, where the buildings do not exceed two or three stories in height, the available standpipe storage has proven timely and sufficient in the amount of water furnished for quenching incipient fires. But it must be conceded that this small storage affords little security in case a fire has reached considerable proportions, for then a pressure and volume of water are needed higher and larger than the standpipe can supply, and dependence must finally fall wholly upon water delivered directly from the pumping engines. In such an emergency should the steam be so low in the boilers that the pumps cannot be speedily brought into action a failure of fire protection ensues.

A failure to have the fires under the boiler and the steam pressure in a state for the prompt rendering of efficient fire protection in towns having a standpipe system of water-works, but in reality depending upon direct pressure from the pumps for fire service, is but a natural result of efforts to secure economy in expenditure on the operation of a water-works of this kind. As a matter of fact, the conditions are such that to realize prompt and efficient service from the water-works the steam pressure should not be allowed to run low, the fires under the boiler should not be out and more or less night attendance should be provided. In the rendering of a good service under such conditions it is quite probable that the annual expenditure for operating the water-works would almost, if not quite, equal the expenditure were the works operated entirely by direct pressure, particularly if the standpipe be considered dispensed with and the interest on its cost and the cost of maintenance be credited to operating expenses of the direct-pressure system, or if due consideration be given to the advantage and value of expending an amount of money, equal to the cost of the standpipe, in improving the water supply, or in the purchase of a pumping engine of higher duty than is ordinarily used in small water-works.

Occasionally a locality is encountered where a standpipe, located on a natural elevation, can afford a good service to residences on plateaus of high ground and a good fire service to the business portion of the town on low ground, even to the extent of the full storage capacity.

3. When the available pumping capacity is less than the occasional rate of consumption. Conditions of this kind in connection with a standpipe system of water-works are unusual, though occasionally found, and must place a town in a rather precarious position with respect to protection from fires. It is usually not practicable to secure standpipe storage in an amount that will admit of any protracted demand for water in excess of the capacity of the pumping machinery. Reserve machinery is needed.

On the whole, it is somewhat difficult to define the precise adaptability of a standpipe to water-works purposes. An answer to this question depends upon special and local conditions. However, in the choice of it for that purpose, it would seem as though there were mingled with a necessary demand motives of expediency and, to a certain extent, popular sentiments of fashion ; of fashion, in many small towns at least, because of the conspicuousness and striking appearance of a standpipe ; of expediency, because of the royalties

which are supposed to attach to the use of the direct pressure system of water-works on account of patents issued upon it in connection with certain pumping machinery automatically governed. By this time any sentiment of fashion must have lost much of its fervor, but questions of expediency may yet engage consideration.

But apart from considerations of fashion and expediency, and purely upon a point of merit, the standpipe, as a useful and necessary part of a water-works system, appears to be much overrated. In considering this question, the writer took occasion to write to the mayor of a town for which he (the writer) had designed a direct-pressure system of water-works, regarding the character of service rendered by the works and what advantages, if any, the city, after a five years' trial, would expect to derive from a standpipe. The reply is so much to the point that it is here by permission quoted in full:

"Will say that the adaptability of direct pressure for our city is most satisfactory and excellent. No annoyance or complaint of slack water from pipes has ever been made. The consumption service is first class and praised by everyone. The fire pressure is simply immense. To illustrate, on last Saturday night one of our large elevators caught fire and was discovered at 2.30 in the night. Pressure was ready by the time couplings were made and it was of such good force, notwithstanding the saving of anything looked like a hopeless job, that the fire was stopped where we found it. And this has been the history of all our fires. We would not change it for standpipe. The cost of operation is but little more, in fact, when we take into consideration the expense and repairs necessary on standpipes, I think the direct pressure is quite as cheap and a great deal more satisfactory. Our system is highly satisfactory in all respects."

This town has a population of about 2000 people, and the water supply is from a large open well, sunk 30 feet into water-bearing sands. The works cost $25,000 and the annual operating expenses, including interest on bonds at 5 per cent., is recorded as being $3250. It is very doubtful if any such unreserved statements can be made of the service of standpipe systems of water-works in many towns where operation is suspended during the night hours.

Various towns and cities which have built direct pressure water-works have found no occasion to add a standpipe.

The custom of combining water service for domestic and industrial purposes with that of direct pressure fire service will undoubtedly continue to prevail in many places. But with a water-works performing such a dual service, the mere fact of a standpipe being connected with the system for purposes of domestic and industrial service only, need not interfere with the rendering of a prompt fire service, provided the machinery be maintained in readiness to perform such service at any moment and the standpipe be speedily cut off from connection with the mains. The general tendency, however, is to bank the fires under the boiler at night and to rely upon the storage of the standpipe, thus rendering impracticable fire service of a high degree of efficiency during a portion of the twenty-four hours.

In a readiness for prompt and positive action during all hours lies the most valuable consideration for the protection of property. It reduces the risk of loss by fire both to the insurance companies and to the property-holder, and this reduction of risk will, in one way or another, revert to the interest of the property-holder, and indirectly to that of the town. In fact, such a service in itself becomes, in a measure, an assurance against fire losses.

Should a community feel the additional security afforded by a continuous direct-pressure service, or by providing such attendance that the service can be promptly made direct-pressure to be worth the necessary expenditure of time and money, the standpipe becomes a superfluity, and if we may infer anything from such testimonials as are contained in the letter before quoted, and from the continued use of direct pressure

by towns originally constructing water-works for such a service, it is to the effect that small towns can afford the direct-pressure system and are benefited by its use. Should, however, a community think night attendance superfluous, then a standpipe becomes advisable, because it would afford greater protection than would a sleeping direct pressure system of water-works.

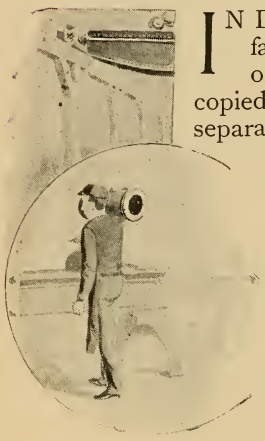
The amount of automatic government actually required in connection with the process of pumping into a closed distribution is, perhaps, overestimated by some, inasmuch as the fluctuation of pressure in a system of pipes, as the result of changes in the rate of consumption, constitutes in itself a pump governor. The tendency of a pumping engine at work is to increase its speed with every fall of water pressure and to run slower as the water pressure increases, thus automatically adjusting its speed to one suitable to the maintaining of a uniform pressure, and, therefore, to the rendering of a uniform service. In practice this effect is fully and satisfactorily developed until the limit of a safe rate of speed is attained, when it becomes necessary to bring reserve machinery into action, thus rendering permanent a uniformity of service. Such protection as a pumping engine may need to prevent a dangerous speed in case of a sudden drop of water pressure caused, for example, by the breaking of a main or an injury from water hammer, can be readily afforded by several simple devices.

In conclusion, considering the questionable utility of standpipes in many instances, considering the better protection of property and the generally good service which may be economically attained without them where a dual service is to be performed, considering the difficulty of securing a material and character of construction free from serious defects, especially in those sections of large pipes composed of thick and heavy plates, and considering the various dangers to which standpipes are exposed and the heavy expense necessary to avert these dangers, it would appear advisable to gradually abandon the use of such structures. The expediency among engineers of adopting such a course is a matter for personal judgment and special investigation in each instance as it may arise

EMERY AND EMERY WHEEL TESTS.*

By T. Dunkin Paret.

As president of one of the largest firms of emery wheel makers in America, T. DUNKIN PARET has made emery and emery wheels a subject of close study for many years, and what he says of it may therefore be accepted as expert information. How to properly test abrasives and grinding apparatus is of special interest, and Mr. Paret's remarks dispose of the matter in a clear and direct way.



IN Dr. J. Lawrence Smith's famous test of the value of emery, which has been copied by all his followers, separate grains of emery, not bound to each other or to anything else, but rolling and moving freely, are rubbed between two pieces of glass or between glass and agate. If these grains are loosely aggregated or if they are of bad shape (for instance, flat and thin, with splintery edges), they will, being unsupported, crush down rapidly between the hard opposing surfaces, while fragments of diamond or sapphire would stand up longer and do more work.

The practical question, however, is, how many modern processes reproduce Dr. Smith's test conditions. Emery is principally used on wood and leather wheels, in solid wheels and in the form of emery cloth or paper. It is also used on the lapidary's wheel. If the latter is a lead wheel the emery becomes embedded in the lead, the lead being selected because it is soft enough to allow of the emery grains sinking into it, and of being supported and backed up. When used on the wood and leather wheel, emery is attached to the leather band by a coat of the strongest, toughest glue. The emery is forced into the hot, plastic glue, which fills all interstices in the grain, adapts itself to every peculiarity of shape, and then hardens into a perfectly fitted bed or backing which supports and braces the grain. When used in solid wheels, emery is still more thoroughly braced and backed up, for it is first mixed with a base and then united with such base by gums, glues or cements, aided by the processes of slow drying, baking heat, vitrifaction, tamping and hydraulic pressure. When emery is used to make emery cloth and paper, it is also bedded in and backed up by glue.

In not one of these cases do the emery grains have any free motion of their own. They do not change place in relation to each other, and are not worn out by the friction of emery with emery. They do not break down and crush to pieces, for they are not only backed, but surrounded by their protecting matrix, and so cannot flatten, spread and squeeze apart as does a free, unsupported grain of which only a small part comes in contact with the opposing surfaces. Still another vital condition of Dr. Smith's test is lacking in the cases of the lead wheel, the leather-covered wheel and the emery cloth and paper. In these cases the emery is not rubbed between two unyielding surfaces, such as glass and agate, but between one yielding and one unyielding. Before the grain can crush, the leather, generally chosen for its sponginess and compressibility, will yield—the lead will allow the grain to sink deeper in its surface, the cloth and paper will do the same. These latter, so thin as to possess little compressibility, are often backed up by the human hand, which affords the same cushion as does the

* An extract from a lecture delivered before the Franklin Institute of Philadelphia.

spongy walrus or sea horse-hide. Of these differences in the conditions of use the ordinary buyer takes no more note than does the professional expert. He applies, in a rough way, the same sort of test as does the expert—a test which shows only what the emery will do under conditions entirely different from those in which it will be used. He placed some of the emery on a smooth, solid piece of metal, and presses it as hard as he can, and with a sliding motion, with another piece of metal. If the grains are loosely aggregated or badly shaped, they crush to pieces and the emery is condemned. Another test is to place the emery in the palm of the hand and rub it together with the thumb or finger. Here the emery is used as an abrasive agent to destroy itself. The thin edges and sharp corners are ground off and the emery is condemned as soft and dirty.

It appears, therefore, that looseness of aggregation, or friability, and also the shape of grain, may be of importance. It is in the larger grains that friability shows most markedly, and it is quite probable that this friability differs very greatly in grains of different size. If emery is a varied mechanical mixture, minute subdivision may lessen the variety of materials in each grain and so alter the standard of cohesion and aggregation. Where the grain, in crushing down, sets free particles of pure sapphire, it seems clear that these will not crush to pieces as the more heterogeneous grain did. Even if a coarse grain were proved too friable for some special work, it would not follow that finer emery from the same ore was also too friable. It is an important fact that the proportion of coarse grain in use has greatly diminished and that few processes really demand a very coarse and a very resisting grain. The manufacturers of plows and of fire-proof safes, and the workers in granite are those who seem most inclined to use coarse emery. The coarser it is, the more resistant must be the grain, for the more it projects beyond its glue bed, the more easily will it break off or crush down. It is an interesting fact that emery which is pronounced too soft for such use may be adapted to it by special processes. Whatever machine or process may be used to accomplish this, the principle of its operation is to abrade the emery by friction against itself till sharp points, brittle corners and loosely adhering particles are removed.

Concerning the comparative values of round-grained emery and that of other shapes, much difference of opinion exists. The rounded or cubical grain of large size will certainly be most resistant, and, in all processes which reproduce the conditions of Dr. Smith's test, will probably be most valuable; but it does not seem evident that any advantage will attach to such shapes when they are embedded in a solid mass. A rounded or cubical grain of the finest grained, hardest and most compact ore would probably be the best for granite workers, because their processes are such as to crush a friable grain. It is this fact which has led to the growth of a new industry in the manufacture of artificial abrasives. Chilled shot and crushed steel have already won a position among stone workers and will probably have lasting and increasing sale. The makers of crushed steel report that in 1890, their first business year, they sold 230,000 pounds, which sale increased in 1892 to 460,000 pounds.

A chilled shot and a grain of Westchester emery, loosely aggregated and bristling with points, afford extreme contrasts. Our facts lead to the belief that loose aggregation is not a serious defect, provided that the particles are hard enough. The inference from this statement is that abrasive effect is proportioned to the hardness of the particles. But Dr. Heddle's file test, like the glass and agate test of Dr. Smith, lacks the principal condition in the modern use of abrasives. That condition is high speed. Penetration is effected by velocity, and abrasion is effected by the points of one substance penetrating the substance of another. A board is harder than a candle, yet it is said that a candle can be shot through

a board. Glass is harder than lead, yet a bullet of lead will make a clean hole through a window. It seems possible that a like rule may hold good as to abrasives, and that mineral grains may, if used at the right velocity, penetrate substances harder than themselves and prove satisfactory agents of abrasion.

On still another important point does Dr. Smith's test fail to meet the requirements of practical use. It takes no note of the pressure required. If a grain of crushed steel or a diamond gem be embedded in the face of a solid emery wheel, these two articles would abrade through the use of whatever projecting points they might present. As the points wear off, flat faces would appear, destitute of cutting power, and no further abrasion would take place until pressure enough had been applied to crush the grains of diamond and steel and manufacture new points for them. The harder and more resistant the grains were, the greater would be the pressure needed to effect this. The criterion which demands the extreme of hardness, fineness, purity, compactness and resistance in abrading minerals, is one which calls on the manufacturer for a wasteful expenditure of power, which forces on the labourer undue physical strain, which prevents his attainment of manual skill, and which exposes him to unnecessary danger. This criterion has made durability the prime requisite in abrading materials and tools—a durability which the buyer demands without reference to the cost of his product, or to the welfare and safety of his men.

Resistance of material calls for resistance of worker, and that abrading material is best which does equal work in equal time with the least possible power and pressure. Such adaptation to its work is not likely to be found in any mineral of extreme purity or uniformity of composition, whose texture is dense, whose grain is fine, whose cohesion is great. It is more likely to be found in a mineral of such friability and such varied composition as cause it to break up into changing and irregular forms under moderate pressure. While I consider the facts thus far stated unquestionable and the inferences from them correct, I have to avow, regarding emery and other abrasives, that there are few exact data to demonstrate my inferences. The greater the consumption of abrasives and the more varied their use, the greater is the divergence of opinions—the more hopeless the confusion—the deeper the distrust as to any scientific basis in the grinding industry. The men who employ licensed firemen to run a steam boiler, and still further protect themselves by the periodical test of their boilers, give no thought to the latent explosibility of solid emery wheels in charge of common labourers. The railroad, which sends in to the founder its own chemical formula for car brasses, pays no heed to the inherent safety of a vulcanized emery wheel or the inherent danger of a vitrified one. The manufacturer who insists on having the candle-power of his electric light guaranteed, and the horse-power of his turbine or engine measured by a dynamometer, buys the lowest-priced emery wheel he can find, but never discovers the cost of that wheel's product.

This degradation of the grinding industry is due, in part, to that criterion of hardness in abrasive material which has made weight and strength the measure of the human grinder. It is due also, in part, to the fact that grinding problems are so obscure and difficult to the skilled mechanic that he remits them unsolved to the unlearned workman. This degradation of the grinding industry goes back to early times. In the Royal Museum at Berlin is a painting by Gerard Ter Borch, of Deventer, probably executed about 1650, which is marked by all that detail which generally characterizes painting of the Holland school. This picture represents "The Grinder's Family." The work-room is a tumble-down, wretched shed, attached to the dwelling-house. Only one member of the family is at work, unless that operation can be called work in which the mother is engaged. She seems to be searching in the hair of her

young daughter for something that ought not to be there. The grown son, with almost a simpleton's face, and with tattered garments, leans idly against a post. The old father has a wide shelf, just level with the top of the grindstone, and lies upon it at full length upon his stomach, while he presses a scythe upon the grindstone. The other scythes lie out of reach on the floor. The mandrel of the stone revolves in an uncovered groove in a beam, and a notch in that beam holds a wooden wedge to keep the mandrel in its place. Everything indicates that activity is at a big discount—art at a low ebb and wages lower still.

It is unfair, you will say, to steal this two hundred and forty-four year old example from a pastoral country like Holland. Why not go to a manufacturing country in modern times? Why not visit Sheffield, for instance? I did visit Sheffield in 1892. I asked a master cutler to show me the latest thing in grinding. He said there was no late thing. I asked him about abrasives and he said each individual grinder supplied his own, buying a few pennysworth of emery at the nearest chemist's and having it chalked up against him just as he had his beer chalked up at the tavern. He said the grinders could generally be found at work when they had no money to spend, always providing there wasn't a football match on hand. He told me to visit Rodgers' and see what they did and then he would take me outside the town to mills hundreds of years old and that I would find the tools, the processes, the conditions identical. The factory building he called "a wheel," and the vaulted dungeons, whose windows had all their glass shattered to let in the light which the splash and slop of the wet stone obscured, he called "troughs." A strap (belt), a stone, a razor and a grinder were what constituted the grinding industry. I ignorantly spoke of the grinders as "men," but he said it was a common Sheffield saying, "he's not a man; he's only a grinder." I did go to the main establishment of Rodgers and then to a "wheel" in a valley some miles out of the city. The "wheel" was a long, dull building of cut stone. The newer part was about 100 or 150 years old, while one wing was much older—too old for the date of its founding to be remembered. The grinder was a man over sixty, and he assured me that his father and his father's father had also ground razors there. As I talked with him two younger men examined a pile of apparently worn-out grindstones, which they said were bought second-hand, when too small for other use, and, selecting one of the quality desired, split it in two pieces because it was too thick. From this dilapidated building, from these scant tools and crude processes, were evolved by grinders not thought worthy to be called men, those blades which have made the name of Rodgers famous. Inherited skill and restriction to one narrow branch of work take the place of modern improvements.

In America the tyranny of the trades-union has not gone so far as to insist that only the sons and grandsons of razor grinders shall learn to grind razors. Instead of old processes, perpetuated unchanged for hundreds of years, there are all the newest wrinkles. We find automatic grinding machines, almost human in their complication, and which render brains almost unnecessary to the workman; and others which look beautifully on paper, and either go to the waste pile or swell the maker's account of "returned goods." There are the newest wrinkles, but no rules—the most ingenious devices, but no accepted standards—the most varied opinions, but no authorities. While grinding processes are complicated and solid emery wheels high-class tools, and while economical grinding demands conditions based on the careful study of educated mechanics, no one establishment uses enough to enlist the interest of the educated man. Abrasives are committed to the lowest class of labor, and reports as to results drift through circuitous channels to the buyer, whose next purchase is based on the latest and most distorted report. The name of "Wellington" is so potent that

often the grinder will use no other brand of emery, though he will take any and all kinds of material without discovering any difference, provided they are poured out of a "Wellington" keg and have a color not found in the original material.

It seems clear that current opinions about abrasives have been based too much on cabinet specimens and laboratory experiments, and too little on the average products of the mine and on the conditions of modern work. It seems demonstrated that chemical analysis does not gauge accurately the abrasive capacity of any mineral—that the hardness of such material does not bear a definite relation to its purity (meaning thereby a high percentage of alumina), and equally clear that mere hardness is not the prime requisite. It seems clear that abrasive capacity depends largely on some unexplained peculiarity of structure. It seems evident that speed, time and pressure are factors too little considered in connection with the problem of safe and economical grinding. It seems settled that external appearance is a poor guide to grinding capacity ; that colors, shape of grain and attractability by the magnet are not trustworthy indications. It seems clear that commercial abrasives vary in quality, and that their acceptance or condemnation depends on prejudices and notions rather than on ascertained facts as to the cost of product.

Some of the causes which lead to variable and contradictory results with abrasives are those common to shop practice, but which produce far greater effects with the emery wheel than with the lathe or planer. The effective work of an emery wheel is based on its speed of a mile a minute. The correct speed is less likely to be maintained, because the pressure against the wheel is heavier and more variable than that in a lathe. The lathe tool presses with a sharp point only against the revolving work, and is so set that, after the first cut, the pressure scarcely changes.

The grinder, however, forces his work against the wheel with greatly varying strength, and sometimes adds to direct pressure a heavy leverage. I have often seen wheels slowed down till they almost stopped. Pulleys of too small diameters are used, and belts which are too narrow. Slip of belt and diminution of speed are potent factors in the problem.

Another equally potent one is discontinuity of contact. A wheel may run a mile a minute and yet be so out of round or mounted on such a light machine or shaky floor that vibration and chatter interfere with continuous contact. Instead of a mile-long file passing over the work in a minute, it is sometimes only an eighth or a quarter-mile file. I have examined wheels whose continuous stream of sparks suggested continuous contact, and found that only two or three inches of the surface had come in contact with the metal. The custom of imputing all variability of result to defect in the wheel and the overlooking of variability in the metal operated on is another cause of contradictory result. A class of wheels which had long suited a plow manufacturer was at last repeatedly condemned and the wheel declared worthless. After a very long interval it appeared that the plows had been changed from one homogeneous thickness to three sheets of varying temper. A class of wheels was condemned which had long suited for car brasses, and only after long delay was it made known that the first metal was yellow brass and the last, phosphor-bronze. I have lately discovered, by use of an improved testing machine, that the quality of the test bars of cast iron is more variable than the quality of tanite wheels.

What, then, is needed, to clear up this confusion?

It seems to me that the thing most needed is a practical testing machine. Such a machine should be run by an independent engine to secure uniform speed. Pulleys and belts should be so proportioned that no slip shall occur. Floor and machine should be so solid as to do away with vibration. Test bars should be employed of the most uniform quality. And then a series of experiments should be carried out so as

to establish definite standards. It should be ascertained what is the least pressure per square inch at which a cubic inch of test metal can be ground off in the least time with the least consumption of wheel material. In other words, the final economy of the process should be demonstrated, taking into strict account the consumption of wheel material, the amount of metal ground, the time occupied, the speed employed, the horse-power expended and the pressure exerted. Thus will gradually arise a fixed standard as to what constitutes a good emery wheel, and the buyer will demand an article of known and certified productive effect whose cost of product is also known. Thus will arise on the grinder's side a demand for those wheels and those abrasives which entail the least bodily fatigue. Thus will arise a public opinion which shall hold to strict account those reckless buyers who put wheels of known dangerous quality in the hands of their employees. For this machine should not only be used to ascertain the economic value of abrasives, but also to demonstrate the relative safety of solid emery wheels.

ALEXANDER GRAHAM BELL,

The Inventor of the Telephone.

WITH the publication, in this number, of several articles on telephony and telegraphy, it would seem appropriate to give space also to an account, however brief, of Alexander Graham Bell, whose investigations and practical developments in the field of electrical transmission of speech have given us the telephone of the present day. It is with special pleasure, therefore, that the appended particulars are reproduced from a much-condensed biographical sketch published in The Electrical Trades Directory, of The Electrician, of London.

Alexander Graham Bell was born at Edinburgh, Scotland, on March 3, 1847. His father and grandfather were both teachers of languages, and his father, Alexander Melville Bell, long enjoyed a reputation in the field of philology and linguistics, being the deviser of an ingenius system of "visible speech." He intended that his son should follow his profession, and therefore early gave him instruction in the anatomy of the vocal organs, their various functions, and the different subjects belonging generally to the science of vocal physiology. When quite a child, Bell was told by his father of an automaton speaking-machine which he had seen. The boy was so interested that he determined to attempt the construction of such an apparatus himself, and he, then and there, invented a speaking machine, built it and made it articulate one or two simple words. While at Elgin, in Scotland, he became interested in the important work done by Helmholtz, relating to the quality of vocal sounds.

In 1865 the family removed from Scotland to London, and about 1866, at Bath, in England, Bell conceived the idea of following up Helmholtz's synthetical experiments in the reproduction of sound, by attempting to transmit speech electrically. Between the years 1867 and 1870 he made numerous electrical inventions based on the Helmholtz vowel apparatus, and, before he left England, had resolved to pursue one of these inventions, that of harmonic or multiple telegraphy, to a practical outcome. The idea of actual speech transmission was running in his mind all this time, like an undercurrent of thought that he could hardly formulate in definite expression; but it gradually took

clearer shape, and Professor Bell has stated on the witness stand that to friends in England, before 1870, he avowed his belief that we should "one day speak by telegraph."

In August, 1870, the Bell family emigrated from England to Brantford, Canada, and in April, 1871, Bell went from there to Boston, on the invitation of the Boston school board, to carry on a series of experiments with his father's system of "visible speech," or physiological symbols for the deaf. He remained permanently in the neighborhood of Boston from October 1, 1872, until he removed to Washington in 1881. From the very moment of his arrival in Canada, in 1870, up to the beginning of 1874, his mind was full of the scheme for the multiple transmission of telegraphic messages by means of musical tones, and he had other telegraphic inventions also in hand; but the old idea of speech transmission was persistent in claiming his attention, and gradually his thoughts and energies were narrowed down to this one field of investigation. He has himself narrated more than once the manner in which he proceeded, stage by stage, from his experiments with phonautographic apparatus, human ear-drums and apparatus for obtaining undulatory currents, up to the period when he and his assistant, Mr. T. A. Watson, were able to talk to each other telephonically over a short line in the Boston University, and when, by rapid strides, the crude apparatus was improved and brought to a fair degree of efficiency.

The first tests of the telephone as a speech transmitter were watched with great interest by many scientific men to whom Bell communicated his results freely, and from whom he received many valuable suggestions; but the press and public were skeptical in regard to the reports which began to circulate. Bell's first public lecture on the telephone was delivered before the Society of Arts at Boston, on May 25, 1876; but the first transmission of speech over a real line was effected in August, 1876, at Brantford. Bell hastened to patent his invention, and in the same year exhibited it at the Philadelphia Centenial Exposition, where a memorable display of its speaking powers was made on Sunday, June 25, 1876, before Sir William Thomson, now Lord Kelvin, the Emperor of Brazil, Prof. T. Sterry Hunt, Dr. Draper, Dr. Koenig, and others.

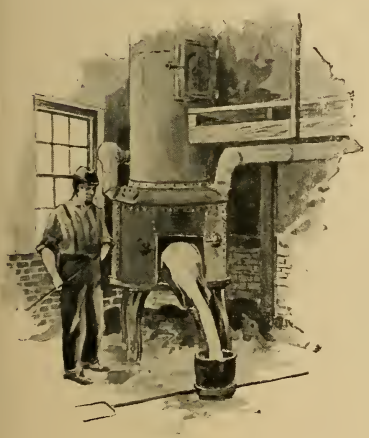
From first to last Prof. Bell has taken out twenty-one United States patents, as sole or joint inventor, the most important being, of course, the one on which is based the speaking telephone of to-day. The photophone, however, upon which he has worked, stands high also as a scientific achievement. Having received the French Volta prize, he devoted the money to the establishment, at Washington, of the Volta Laboratory, with a view to original investigation in the transmission and reproduction of articulate sounds Prof. Bell has also, to some extent, given attention to devising improved methods of electrical communication between vessels at sea. Of late years, however, Prof. Bell has mainly devoted himself to his original pursuit, namely, the study of the instruction of the deaf and dumb in connection with his father's system of "visible speech," and he has given much thought, with no small measure of success, to the amelioration of the condition of such unfortunates.

Immediately after the invention of the telephone and its introduction into commercial use, Prof. Bell was called upon for papers and lectures, and for a time he yielded to the demand. Among the most noteworthy of his productions are "Researches in Electric Telephony," a paper read before the Society of Telegraph Engineers in 1877; "The Production and Reproduction of Sound by Light," a paper read before the American Association for the Advancement of Science, in 1880, relating to discoveries made by himself and Mr. Sumner Tainter in the art of "radiophony;" and the "Production of Sound by Radiant Energy," a paper read before the National Academy of Sciences, in 1881, relating to further investigations of the same nature.

AMERICAN COAST DEFENSE MORTARS.

By A. A. Fuller.

ARTHUR A. FULLER was graduated at Stevens Institute of Technology in 1888. For one year he was assistant professor of physics and engineering at the Missouri State University, and since that time has had charge of the constructive work of the Builders Iron Foundry, at Providence, R. I., at which the mortars were built of which he here writes.

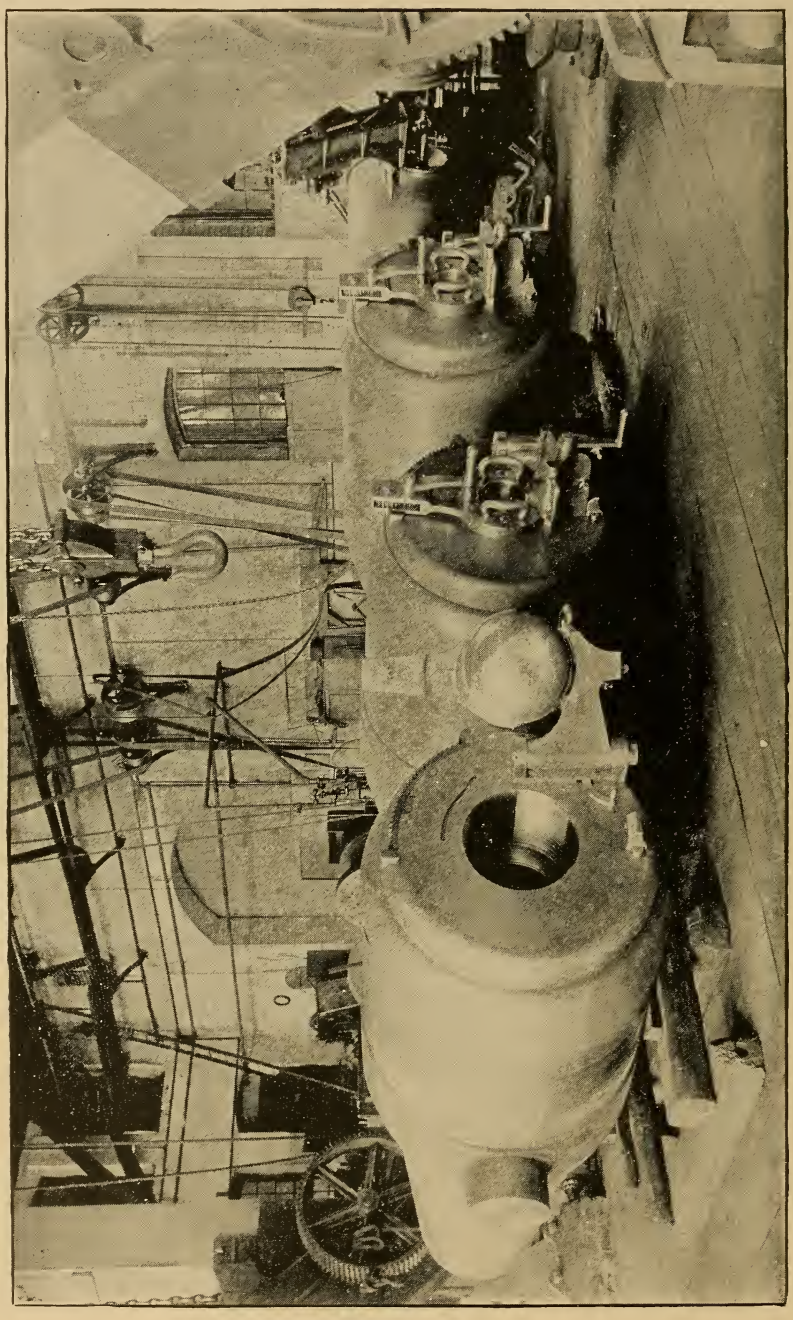


AS a part of the system of coast defense determined upon in 1886 the United States Government decided to use what are officially termed "12-inch, breech-loading, rifled mortars, cast-iron body, steel-hooped, fourteen and one-quarter tons." Seventy-three of these guns have been completed by the Builders' Iron Foundry of Providence, R. I.

The plans of the Engineer Corps of the United States Army call, in all, for six hundred and thirty-two mortars, and it is probable that the remaining five hundred and thirty-nine will be made with steel bodies in place of cast-iron, the increase in weight of shot and charge of powder making it desirable to use stronger material for the body. Foundations and embankments have been begun near many of the American seaport cities which are to receive batteries of these guns. Among the localities to be thus fortified are Portland, Me., Boston, Narragansett Bay, New York City, Washington, Hampton Roads, Charleston, S. C., and San Francisco.

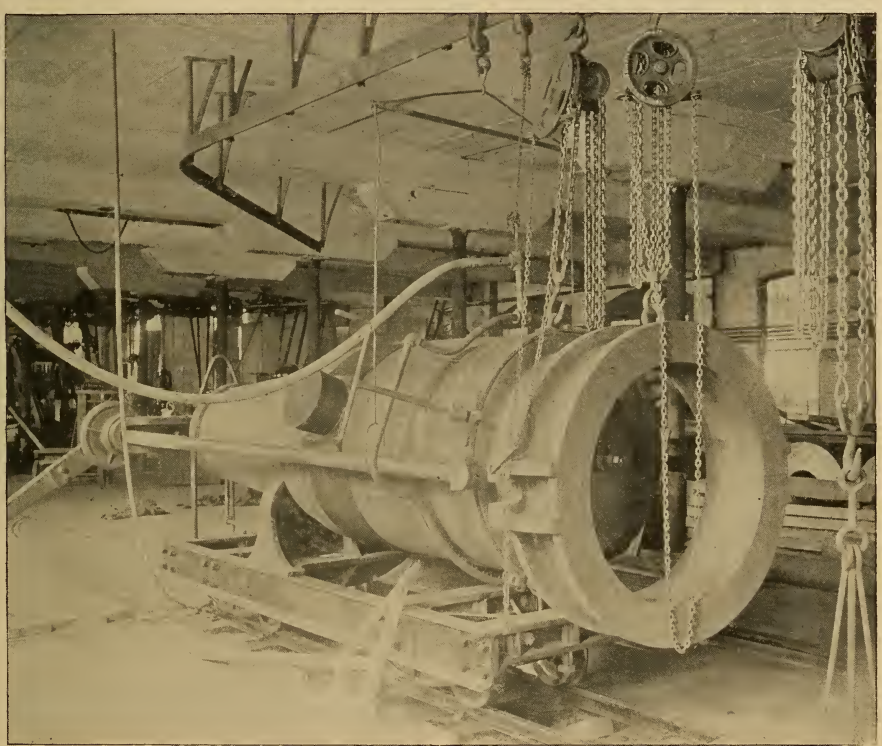
The manufacture of the mortars with cast-iron bodies is of interest, as these guns constitute the highest type of heavy cast-iron ordnance ever constructed. In appearance they very closely resemble the steel breech-loading rifles made by the United States War and Navy departments, except in length, which, in the rifles, is about thirty times the diameter of the bore, and in the mortars, only ten times. The cast-iron bodies have a 12-inch bore, are 129 inches long and 31½ inches in diameter, and the diameter over the steel hoops, which are shrunk on the bodies in two rows, is 42½ inches. The body is cast vertically according to the Rodman process, the hole being cored through the entire length of the body. The mould for this purpose is built up in sections held in a cylindrical iron flask resembling a piece of large flanged pipe. These sections are placed one on top of another and are securely fastened together, forming a cylindrical mould about 17 feet high and 33 inches diameter. The core is of one piece built upon an arbor covered with a layer of rope, a layer of sand and an exterior coating of plumbago.

The metal is melted in what is known as an air furnace, the iron being separate from the fuel. The results are more reliable and the iron is more homogeneous than could be obtained with the ordinary cupola. About six hours are required to completely fuse the metal and from two to six hours longer are necessary to bring it to the proper state before pouring. The amount of coal consumed is about 14,000 lbs., or thirty-seven per cent. of the weight of metal, which is nearly four times the amount of fuel required by an ordinary cupola.

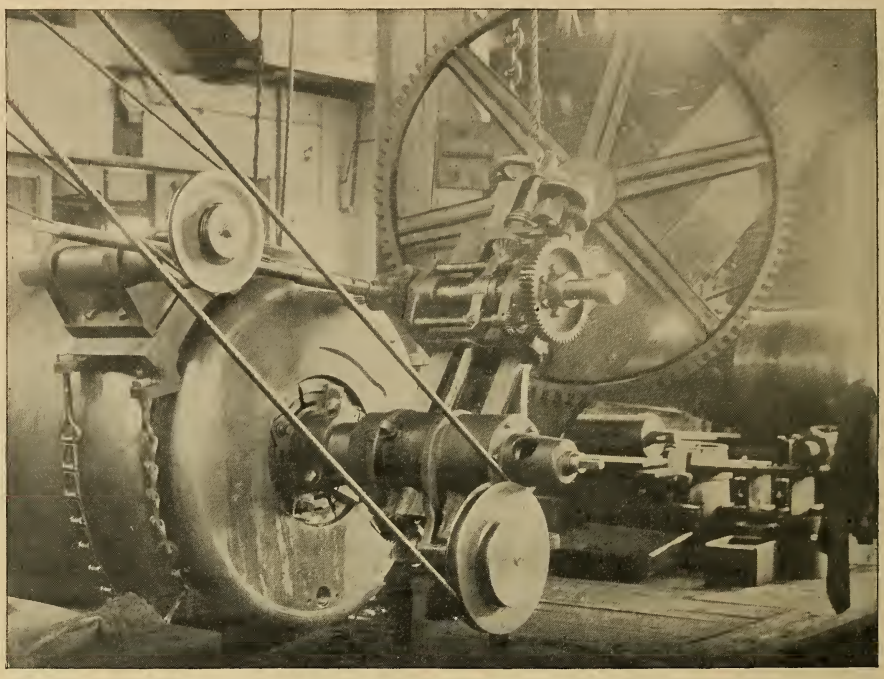


A ROW OF 12-INCH MORTARS IN THE SHOPS.

The iron, when tapped from the furnace, flows through a long trough of fire-clay directly into the mould, displaying the most brilliant boiling and scintillating effects. Cooling is materially assisted by circulating water through the core arbor for twenty-four hours. The core is then removed and the circulation continued with water in direct contact with the interior of the casting for an additional period of forty hours. The casting thus obtained has an average tensile strength of 33,000 lbs. per square inch. The metal at the bore has an initial compression of from 5000 to 9000 lbs. per square inch, and the metal on the exterior has an initial tension of about 4000 lbs. per square inch. About one-fifth of the casting is cut off for a shrink-head, and test disks are cut at each end of the gun from which numerous test specimens are taken. The process of machining is interesting because of the accuracy required to keep within the small limits allowed and the necessity of having the parts interchangeable. The roughing out is done in a large lathe with a boring bar attachment instead of a tail stock. The gun is held and driven by a chuck on the face plate, and the other end of the casting runs on a semi-circular bearing or steady rest. The boring bar has no rotary movement, but is fed towards the face plate, and carries a reamer-like cutter which enlarges the hole by several cuts to 11.9 inches. At the same time ordinary tools turn down the chase or forward taper and parting-off tools are run in nearly to the bore, dividing off the discs and shrink head, which are afterwards broken from the casting by wedge and sledge. The



APPARATUS FOR HOOPING THE MORTARS.



THE BREECH-MILLING MACHINE.

outside of the body is now accurately turned to a varying diameter slightly larger than the inside of the hoops which are to be shrunk on. This difference is called the "shrinkage" and it varies along the entire length to be hooped, the purpose being to place each of the hoops under equal tension. Contrary to the custom with long guns the hooping takes place with the axis of the mortars horizontal. The steel hoops, eleven in number, are heated in a gas furnace, the flames playing directly against the hoops both inside and out, heating them to about 500 degrees Fahrenheit. The total expansion is about 0.09 inch in a hoop.

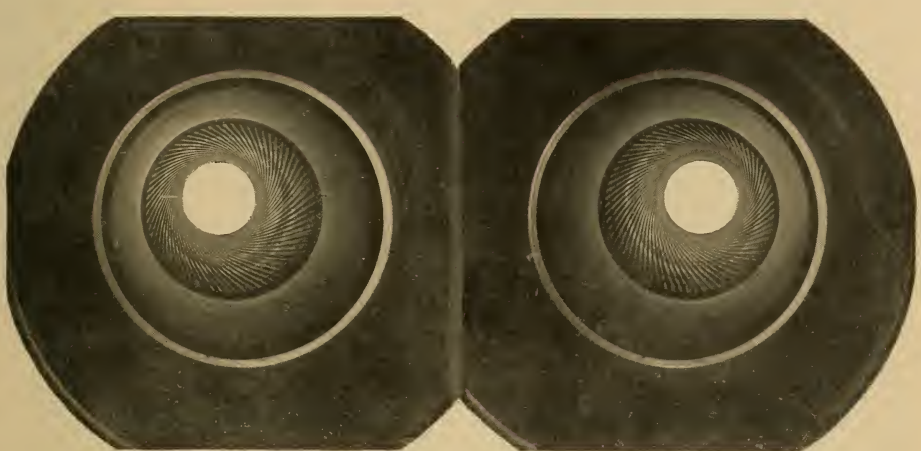
When heated, the hoop is slipped over the gun, and by means of the hooping press a force of 100 tons is exerted to make a tight joint between it and the one immediately in front. A plane of water from a "sprinkling ring" is then allowed to play on the forward portion of the hoop, which soon contracts enough to grip the body. The plane of water is then moved slowly backward until the entire hoop is cold. It is necessary to cool and thus clamp the forward portion before the rest, otherwise the contraction ensuing would open the joint notwithstanding all the pressure that could be applied. The closeness of these joints may be inferred from the fact that after the exterior of the hooped gun is turned they can seldom be detected. The exterior of the first row of hoops is next turned down as carefully as was the body, the second row of hoops is shrunk on in a similar manner, and the entire exterior is turned to the finished diameters. The hoops are so placed as to break joints.

The finished bore must be between 12 and 12.003 inches diameter and straight enough to allow a test cylinder 11.997 inches in diameter and 42 inches long, to easily slip through the entire length. By use of a special lubricant and reamer the bore in cast iron is given a smoothness and polish nearly equal to that of steel.

Few operations in machine shop

practice require as much care as the rifling of a cannon, since so much is at stake. The results of months of labor may be entirely spoiled by a false cut, ruining the body and rendering the steel hoops encircling it worthless. Extra care is, therefore, necessary both in design and operation of the rifling machine, and mechanical contrivances are provided for instantly stopping the machine if any detail gets out of alignment.

Sixty-eight grooves are cut, being 0.379 inch wide and 0.7 inch deep, and having an "increase pitch" varying from one turn in twenty-five calibres to one in forty, the object being to avoid a too sudden initial rotation of the shot when fired. The stereoscopic view of the interior of the bore gives a realistic reproduction of the appearance of the rifling, showing how it can give a twisting or rotary motion to the shot. It exaggerates somewhat the length of the bore because of the difficulty of focussing.



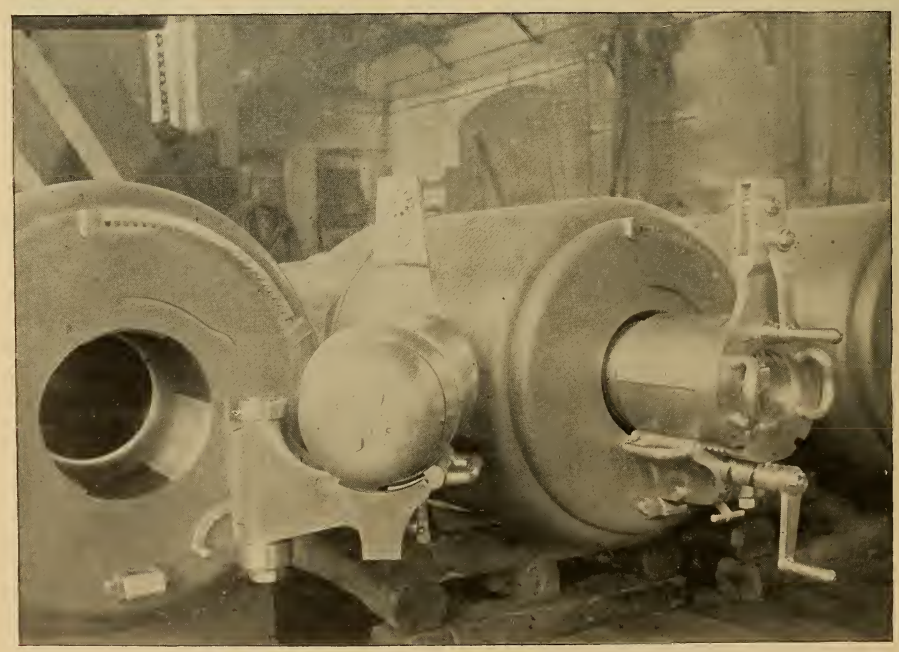
STEREOSCOPIC VIEW OF INTERIOR OF BORE.

The rifling is accomplished by a single cutter or tool, set radially into a sliding cylindrical head which entirely fills the bore. This head is attached to the end of a long bar, which has a reciprocating motion from one end of the gun to the other, similar to the action of an ordinary planer. The bar and head also have a rotary or twisting motion as they move along the bore. At the end of the cutting stroke the tool is made to automatically sink below the surface of the head so as not to drag or score the surface on the return stroke. At the end of the return stroke it bobs up again, ready for another working stroke. Several cuts are taken in each groove, and as the limit is only 0.0015 of an inch, the last chip is often the result of only a mere scrape of the tool.

When threading the breech recess, the gun is not revolved, but a long bar, with a master screw attached, is placed centrally in the bore, and a large nut to receive this master screw is firmly fixed in the bore near the muzzle. The bar is then rotated by a boring machine with a free sliding spindle. As the bar revolves it advances as guided by the master screw. A specially shaped tool attached to the bar cuts a thread which will exactly match the thread of the breech block, the latter being threaded on the lathe which made the original master screw. The threads are slotted out in three places for a space of 60 degrees each to form an interrupted thread for the reception of the breech block. This slotting is accomplished by means of a

special shaping machine with circular feed. The centre about which this tool revolves must be set with great care, as a limit of only 0.003 inch is allowed at this point.

There are three mortises of complicated shape to be cut out of the solid metal of the breech. The illustration on page 60 shows the breech milling machine which is attached to a heavy screw inserted into the breech recess of the mortars. This screw is split and can be expanded in place, holding the machine as firmly as if it were a part of the gun. The machine is capable of drilling and milling. The milling cutters can be fed radially along the arm, by a screw operating the sliding head, or circularly about the axis of the gun by means of a tangent feed screw arrangement clamped independently to the body of the gun. For the irregularly-shaped mortises a forming or profile plate, clamped to the breech face, is used to guide the milling cutter and makes the mortices uniform in all the guns. The illustration on this page shows the breech-mechanism in two positions. The gun at the left is wide open, ready to load ; the one on the right is partially closed. The gun at the left shows most clearly the "hinge block," mortised into the body of the gun, and the bronze "tray" hinged to it and carrying the "breech block" swung to its extreme backward position. The curved "latch" with a handle, seen extending through the hinge block, secures the mechanism in this position. The curved slot directly over the bore receives a pin on the vent cover—a small slide which keeps the priming hole covered until the breech block is fully locked. The catch directly below the bore receives the "tray latch," having a T-shaped handle, seen just beneath the tray, and holds the tray firmly against the breech face of the gun when in the position shown on the right. By comparing the two positions a clear idea can be obtained of how the threads are cut away, or interrupted, both in the breech recess and from the exterior of the breech block.



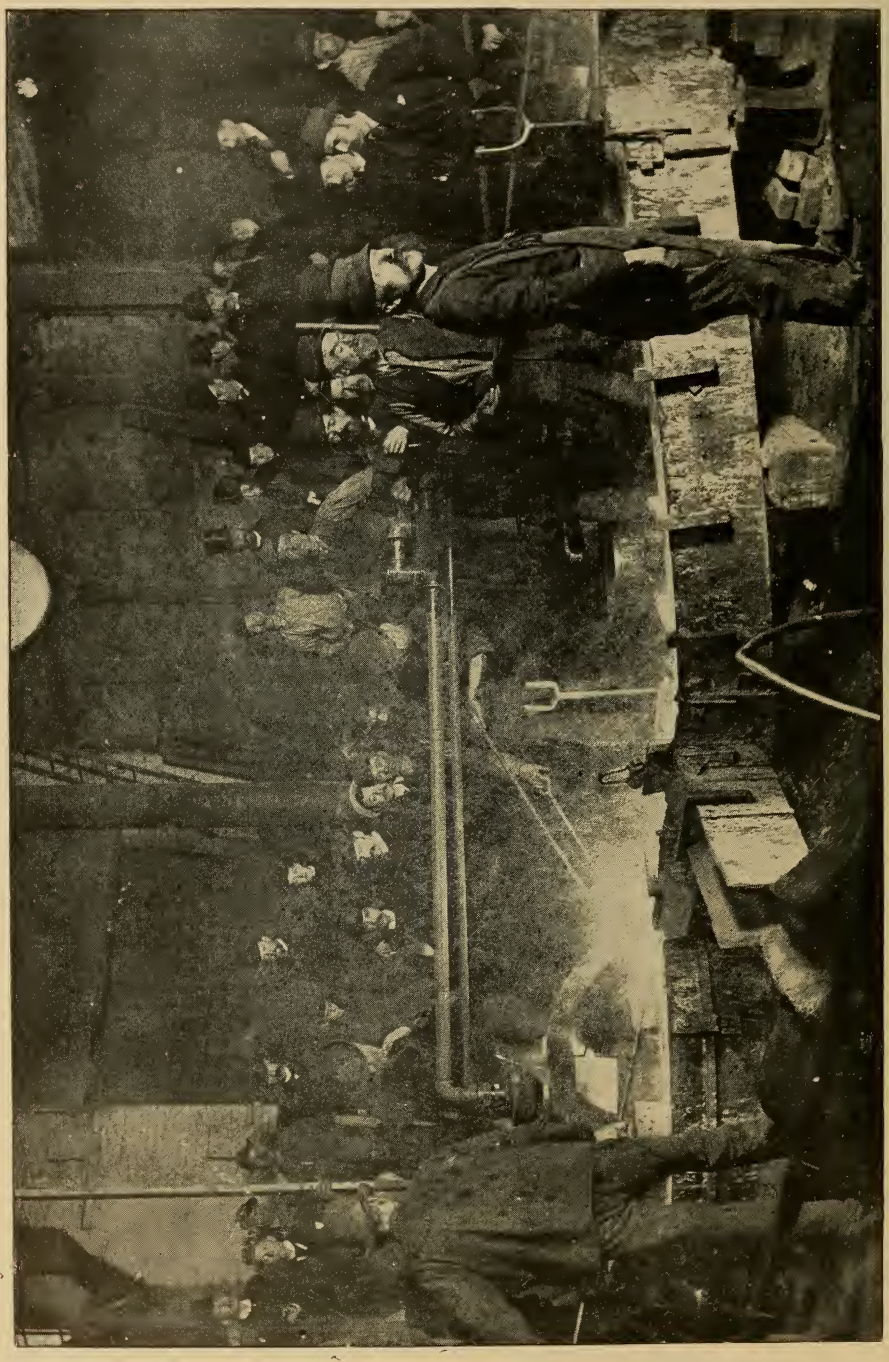
THE LOADING MECHANISM.

The cut-away portion of the one stands exactly in line with the remaining threaded portion of the other, thus allowing the block to be slid into the gun its entire length without being rotated. This is accomplished by turning the lower crank handle. This handle turns the "translating roller," which is threaded into the tray with a right hand thread, and has also a left hand groove, or cam, cut upon its exterior. A stud upon the breech block engages in this groove. When the crank is turned, the roller advances into the tray, and the stud of the breech block advances along the groove of the roller, propelling the breech block rapidly into the gun. When the block is nearly in, the pinion at the top of the vertical arm is brought into mesh with the circular rack let into the breech face of the gun ; then, by turning the upper crank handle, this pinion moves towards the right in the rack, causing the breech block to rotate, its threaded portion coming into mesh with the threads of the breech recess. It is then as firmly locked as though it were cast solid with the gun, the explosive force of the powder not being able to dislodge it from this position.

MORTAR AND CARRIAGE.

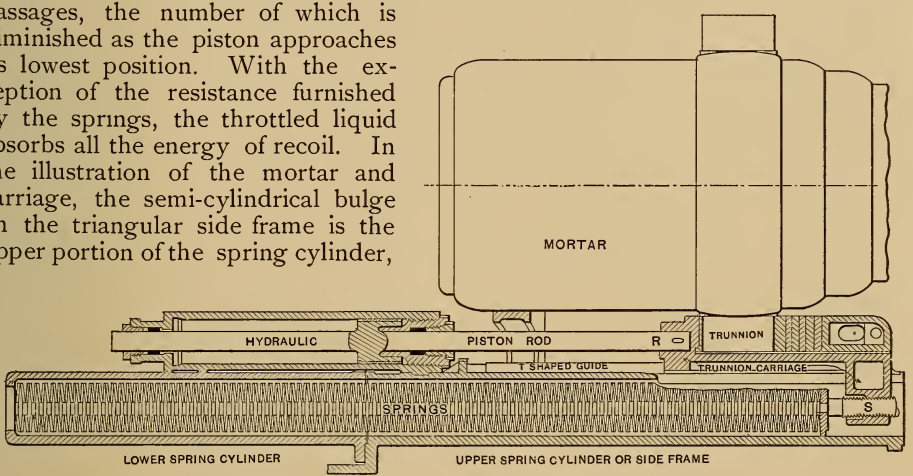
The mortars are mounted in carriages of unique design, the recoil taking place at an angle of 55 degrees with the horizontal. The mortar is held in its uppermost, or firing, position by means of springs, and its recoil is checked by a piston, acting against a liquid confined in a hydraulic cylinder, the out-flow of the liquid being subject to fine regulation. The sectional view shows only one side of this mechanism. The trunnion of the gun rests in the cylindrical bearing of the trunnion carriage, which is firmly gibbed to a T-shaped guide, cast upon the inside of the triangular side frame, upon which it has a movement of about 28 inches.

This carriage has a horn, or projection, at its upper end, which extends through a slot in the side of the spring cylinder and carries a screw S, which rests either upon a series of saucer-shaped springs as shown, or upon a series of helical springs, which have lately come into use. These springs are compressed as the gun slides down-



POURING THE GUN.

ward and are strong enough to return the gun to the firing position. The hydraulic cylinders are situated directly below the trunnions. The piston-rod is keyed into the lower end of the trunnion carriage at R. The cylinder is provided with a by-pass, which allows the liquid to flow from one end to the other through a number of throttled passages, the number of which is diminished as the piston approaches its lowest position. With the exception of the resistance furnished by the springs, the throttled liquid absorbs all the energy of recoil. In the illustration of the mortar and carriage, the semi-cylindrical bulge on the triangular side frame is the upper portion of the spring cylinder,



SECTIONAL VIEW OF HYDRAULIC AND SPRING CYLINDER.

while the lower portion or extension is bolted to this and extends inside nearly to the lower edge of the base ring.

The whole carriage is rotated by means of the crank handle shown at the right of the illustration which, through the medium of a worm and worm wheel, turns a pinion meshing into an internal gear attached to the lower base ring. Between the upper and lower base rings are 24 conical rollers, which allow the carriage to rotate at ease, two men being able to give it a complete turn in one minute. An index ring, graduated to degrees, surrounds the carriage and is firmly secured to the foundation. The surface of this ring and the upper surface of the upper base ring are level with the earth and form the working floor for the gunners.

The gun can be adjusted to any angle between 0 and 75 degrees with the horizontal by means of the spoked wheels, which operate through the medium of a train of spur gearing, the pinions meshing into the large internal racks attached to the mortar. While loading, the gun is depressed to a horizontal position, the projectile is trucked in a special three-wheeled barrow and is guided to a position directly behind the mortar by the tracks seen at the left of the illustration. It is there transferred to a notched scoop on the end of a wrought-iron arm, and is raised by the operation of the tangent screw, just discernable at the back of the illustration, to a horizontal position, level with the bore of the gun. From this position it is pushed into the shot chamber. Eighty pounds of brown prismatic powder follow in a bag, the breech is closed and locked, the primer inserted, the muzzle elevated, the carriage turned so as to point the gun in right direction and all is in readiness to fire. The charge of 80 pounds of powder will produce an initial pressure of about 28,000 pounds per square inch, and give a muzzle velocity of 1200 feet per second to a shell weighing 830 pounds, and, at 45 degrees elevation, gives a range of about six miles.

The shell or hollow steel shot contains about 30 pounds of fine powder. It is cigar-shaped and its front end is turned to a curve called the "ogival." This form offers the least resistance to the air. The rear end of the projectile has a soft metal collar which, when forced into the rifling grooves, gives it

the required rotary motion. The ingenius primer, which fires the explosive in the shell, is also placed at its back end. It does not move from its place when the shot is fired, but is projected forward against a fulminating cap when the target is struck.

The usefulness of these mortars is not a matter of theory. The guns themselves have been tested for many hundred rounds. The carriages are extremely simple in construction and can be operated by unskilled labour under the direction of a gunner. No electricity, compressed air or steam is employed. No pumps, complicated valves, gearing or mechanism are necessary. Even should the springs become disabled, provision is made for prying the mortar back to firing position by the use of ordinary crow-bars. The accuracy of fire is remarkable. Experiments have shown that about seven shots out of ten can be landed on a target representing the deck of a modern man-of-war.

In service the mortars will be separated into batteries of sixteen, each battery consisting of four groups of four mortars. Each group will occupy a separate pit and the whole battery will be well protected by high earth embankments, which will be situated generally some distance inland, entirely out of view from the harbour to be protected. The position of such a battery could not easily be determined from ship-board and, even if located, such a battery would be extremely difficult to silence. The harbour to be protected having been previously blocked off into sections, the position of a vessel entering one of these sections can be determined by observations from proper points, the mortars aimed in season and fired at the proper time by means of electricity. The battery of sixteen mortars can be reloaded and the fire repeated every few minutes, and as each harbour is to have several of these batteries an approaching fleet can be met by a perfect deluge of shot and shell, and one of which will have sufficient destructive power to badly cripple, if not actually sink, the best protected modern man-of-war.

THE OFFICE AND THE WORK SHOP.

By W. H. Wakeman.

THE old saying which informs us that the road leading from the work shop or the engine room to the office is a long one is but too true in many cases. Still, there is no good reason why it should be so. This does not refer to the distance between these places as we ordinarily understand it, but to the fact that so little sympathy exists between employer and employee in some cases, and open hostility in others. Generally a better feeling exists where employees are few in number, and where the employer is personally acquainted with each one of them. The reverse is true where they are numbered by thousands and where but a few of them know their real employers even when they see them.

Let us briefly review some of the causes for this unpleasant state of affairs. In the first place, a great majority of the employees of large corporations and joint stock companies believe that if a man is conducting a business on his own account, he must, of necessity, be making money rapidly, regardless of the state of the market, the price of labour or any other governing conditions. Believing this to be true, and, at the same time, finding that they receive only enough for a comfortable living, they feel that they have good grounds for dissatisfaction; hence the demand for more pay, followed by a refusal, which is, in turn, followed by the strike, the boycott and other unpleasant features of modern labour troubles. Large corporations frequently find themselves confronted by conditions which make it necessary to pass their quarterly dividends, and some go into bankruptcy and become total wrecks ; but still the labourer apparently believes that the business paid large profits, but fails to give good reasons why the money making process was discontinued.

During the recent hard times a certain machine shop was running less than half time, with a reduced number of workmen who were engaged in making tools that were selling at very low prices, and yet some of them were not slow to express the idea that the company was making money, although it must have been evident that the interest account, taxes, insurance, the cost of superintending the work, office expenses and some other charges were the same as when a much more extensive business was conducted. If they really were making money then, what an enormous profit must have been secured under normal conditions, when orders were numerous and prices good.

Many of the employees of large corporations are ignorant enough of the way in which business is transacted, to think that the president of the company that employs them has no fixed salary, but enjoys the privilege of going to the strong box and helping himself

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to whatever amount he may choose to take. They also fail to recognize the fact that in conducting the affairs of the concern he is but carrying out the orders of his superiors, namely, the board of directors, and that he is responsible to them for the faithful discharge of his numerous duties.

Again, employees often fail to take into account all of the cost of producing certain articles on which they labour. The following instance may be an extreme case, but it is a true statement of an actual occurrence. A certain mill hand was very much dissatisfied on ascertaining that he received for his labour on a certain article but 20 per cent. of its selling price, and, yet, to the writer's certain knowledge, the cost of the raw material was more than 50 per cent. of the price of the finished product, and in addition to this, other labour on the same material was paid for, after which the article in question had to be put upon the market, and its price collected. Undoubtedly, this dissatisfied employee was making more money than anyone else concerned in the transaction, and still he considered himself unfairly treated. In a case such as this the distance from the work shop to the office appears great, because the operative looks at it through magnifying glasses and, therefore, does not see things as they are.

Some men are taught from their infancy that the man who invests his capital in mills or factories is the natural enemy of the working class. When they go to work in a new situation they are prejudiced from the start, and it would require extraordinary efforts on the part of their new employer to convince them that he is willing to be their friend. Men are frequently employed on work to which they are not accustomed, and are given small pay at first, with the understanding that as they become more efficient their wages will be increased. After working for a time, with no special effort to make their services more valuable, they remind the manager that an increase was promised them. They are told that this was a conditional promise and that they have not fulfilled their part of the agreement, to which they answer that as soon as their pay is increased they will do better work and more of it. It is proper to say, therefore, that a man should be considered a good paymaster if he pays when the work is done ; and if the average mill or factory hand were called upon to pay for an article before he received it, he would be highly indignant ; yet, this is what he expects of his employer. Employers are not slow to recognize true merit, although they may be so occasionally.

Some time ago a faithful, hard-working engineer found that his salary had been increased voluntarily, or, at least, that there was more money in his envelope than usual, and, on inquiring if it was a mistake, was informed that he was entitled to the greater amount, and that it gave his employers pleasure to thus show their appreciation of his work for their interests. He said, afterwards, that he appreciated this small increase, on account of the way that it came to him, more than he would have done an addition of five times the amount to his salary, given grudgingly or from necessity. This man has found a way to make the road from the engine room to the office a very short one.

The writer once agreed to work for a joint stock company at a fixed rate of compensation, which was to be increased at the end of three months, provided the services were satisfactory. When one-half of that time had expired, the stipulated increase was found in the pay envelope, having been freely given for value received. Such treatment causes the conscientious workman to feel that he is under obligations to do his best in the interests of his employer, and is a further illustration of a way in which the before mentioned road may be caused to contract.

But, strange as it may seem, it is nevertheless true that it will not do to treat all employees in this way, and that it is quite possible to spoil some of them by kindness. The writer was at one time called upon to adjust some differences between a mill owner and

his engineer, and found that shortly previous to that occasion the proprietor had shown his appreciation of services rendered, by voluntarily increasing the salary of the engineer, and that, contrary to his expectations, the latter, instead of thereafter proving himself more valuable if possible, evidently concluded to rest upon his laurels, and would do nothing more than he was obliged to. A thorough sifting of the case showed that he had adopted this course in order to secure a still further advance in his salary ; this resulted in a change of engineers, and, for him, a reduction in salary.

In many cases, while a large salary is desirable, it is not of so much consequence to the employee as it is to have matters so arranged that he can take some comfort while performing his daily labour, and it sometimes happens that a really competent man goes to a place which is notorious for the way in which life was made a burden for his predecessors. By skillful management, however, he may succeed in bringing about a great change, and not only secure a fair salary, but at the same time compel his employers to respect him and treat him in a deserving manner. This way of shortening the road between the engine room and the office is despised by a great many workmen, who apparently forget that the most ignorant labourer can throw down his shovel, abuse his employer and take his departure, but that it requires good judgment and carefully laid and well-executed plans to cause an obdurate employer to change his tactics.

Occasionally men are found who will not listen to reasonable arguments and who cannot appreciate true merit, but they are few and far between. When a man is so unfortunate as to be employed by one of this class, and all efforts to reform him fail, the best plan for him to adopt is to seek more congenial quarters. The practice of staying where contentment is never known cannot be too strongly condemned ; it is demoralizing in every way and the office and the work shop will never be found close together under such circumstances.

The problem of conciliating capital and labour has proved to be a most difficult one to solve, but if every workman would act on the above suggestion, it would do more to bring about the desired end than all the strikes and boycotts which have occurred during the past fifty years.

The employees of a certain machine shop became very much dissatisfied with their treatment and found it impossible to remedy the evil. They talked the matter over, agreed to leave in a body and did so. There was no strike in the ordinary sense of the word, no boycott, and no disturbance. They simply retired from their positions and found work elsewhere, caring nothing about any one who might wish to try to work where they could not. It would require but a very few changes of this kind to convince even the most unreasonable employer that he is not working for his own best interests, and when this is accomplished, the battle is practically won. When a competent mechanic adopts this method of settling labour troubles he is seldom out of employment for many days at a time. The writer does not wish to be misunderstood in this matter, and would recommend this course only as a last resort, and where the employee is wholly blameless.

As these views will meet with some opposition among workmen, we wish to ask if even the most earnest advocate of forcible measures to settle (?) labour troubles can point out a single instance where such means have brought about a better feeling between the men who provide the money and those who furnish the muscle to carry on great industrial enterprises? Without this good feeling it is impossible to obtain the best results, for, where important service is to be rendered, volunteers are always considered superior to drafted men.

Sometimes, by way of experiment, the most unruly boy in a school is appointed monitor over some of the others, and not infrequently the result is that he becomes an orderly scholar, and this is due to the fact that he is

made to feel that he has some responsibility in the matter. Mill and factory hands are only children of a larger growth, and as soon as they are made to feel that they are not wholly irresponsible, the whole matter appears in a different light to them. The question arises as to the length of time that it will require to give this education. To this it may be replied, that in some cases it would take more than a lifetime ; in others only a short time would be needed. But one thing is certain, and that is, the longer we defer the commencement of it, the later will we be in reaping the benefit of it.

The average shop hand believes that his employer would not voluntarily increase his wages, even though the profits of the business amounted to hundreds of pounds a day, because the proprietor almost always does the cutting down of wages and, even when matters get into better condition, the workman must urge, in a more or less forcible manner, that the pay be restored to its former amount ; otherwise in the majority of cases, it never would be. This is all wrong, for if depression in business cause a reduction in wages, the return of good times should have the opposite effect. It is a poor rule that will not work both ways. We say that the proprietor almost always does the cutting down of wages, and we are pleased to be able to put it in that way, for since this article was begun we have received notice of the fact that the operatives in a certain manufacturing establishment, during a time of stagnation of business, presented a petition, requesting that their pay be reduced to suit the times. Truly, it seems incredible, but we have it on good authority. If their pay were not increased when better times came, the case would be an exceptional one indeed. The office and the work shop are close together there.

In the vicinity of a certain town, a few years ago, a small blacksmith, horseshoeing and repair shop was opened. After the place was fitted up for business in a very modest way, the proprietors had but little more than one dollar left as capital, but the business grew and prospered and now thousands of honestly made wagons are sent out annually from these works, which give employment to 2000 hands. The proprietors of that establishment bought a tract of land and laid it out into building lots which were sold to the workmen in the factory at cost, and they were allowed to pay for them in small instalments. Money was loaned to them for the purpose of building homes for their families, which they were allowed to repay in the same way. Thus, all who desired to could own their homes, and when those who have served faithfully for years, become old and infirm, they receive a pension which is paid to them at the same time that the able-bodied men are paid off. They never have any labour troubles in that place. The proprietors and men are fully in sympathy with each other, and there is nothing to cause trouble. The office and the shop there, too, are very close together.

In conclusion the writer would say, that there is one short, simple rule which, if followed, would wipe out the last vestige of strife between capital and labour, and it is recommended to both : "Do unto others as ye would that they should do unto you."

A HISTORY OF THE TELEPHONE.

By W. Clyde Jones.

W. Clyde Jones graduated from the electrical engineering department of the Iowa State College and, after several years of electrical designing and installation work, became associated with a firm of patent lawyers as electrical expert. A number of contributions by him on electrical subjects have appeared during the past few years in different engineering periodicals.

THE telephone has become such a commonplace appliance of modern life that one seldom stops to think what a wonderful instrument it is, nor yet what a great factor it has become in everyday life. Like other important inventions, it is the outcome of a long evolutionary process.

It was in 1819 that Oersted, a professor in the University of Copenhagen, while lecturing to his class, discovered that a magnetic needle, when held in the vicinity of a wire traversed by an electric current, was caused to assume a position at right angles to the axis of the wire. This experiment, though simple of performance, was a revelation to the scientific world, and confirmed the long-standing suspicion that electricity and magnetism were, in some mysterious manner, related. This was the spark that inflamed the minds of scientific men and led to the unraveling of the apparent mysteries of electro-magnetic action and the founding of the laws of electro-magnetism, to which we are, in such a great measure, indebted for the industrial development of the electrical arts.

Oersted had informed the world that there was a relation between electricity and magnetism, but it remained for Sturgeon, in 1825, to point out that there was not only a relation, but that electricity was even convertible into magnetism. He had encircled a bar of soft iron with a helix of wire and noted that upon the passage of an electric current through the helix the soft iron bar assumed the properties of a magnet. Here was the germ that was afterward developed into the telegraph and the telephone. With the electro-magnet the minds of men naturally turned to the transmission of intelligence to a distance, and in the years immediately following Sturgeon's experiment we find the greatest scientific minds busily engaged with the problem. Neither the laws of the electro-magnet nor the laws governing the passage of a current along a wire, since so admirably expressed by Ohm, were at this time known, and the rapid falling away of the force of the current with increased distance led to the belief that an electro-magnetic telegraph would never be possible. Indeed, in 1829, Professor Barlow, of England, perhaps the foremost scientist of his day, after making an exhaustive study of the problem, published a demonstration, considered at the time conclusive, showing that it would be absolutely impossible to transmit intelligence to a distance by means of the electro-magnet.

But soon the dormant hope was again aroused by the publication of the researches of Joseph Henry, who had so thoroughly investigated the laws of the electro-magnet that no discoveries, except of minor importance, have resulted from later investigation; in fact, the electro-magnet as Henry knew it in 1830 is the electro-magnet as we know it to-day.

Ever since Sturgeon had converted electricity into magnetism, the question ever uppermost in scientific minds was whether magnetism might not, in turn, be converted into electricity. In 1831 Henry and Faraday discovered that magnetism was, in fact, convertible into electricity, and was effected by varying

the magnetic field threading a looped conductor. By this discovery, which has rendered illustrious the names of two great men, the world acquired information concerning the laws of electro-magnetism and the mutual convertibility of the two mysterious forces that immediately removed electrical science from the domain of the purely theoretical and experimental and gave it a place in the industrial world.

The time was ripe for the development of the electric telegraph, and in the early 30's Samuel F. B. Morse had conceived the electric telegraph, which, toward the end of the decade, assumed practical form. With Sturgeon's electro-magnet placed at the distant end of the line, he closed an electric circuit by means of a key, thus causing the electro-magnet to attract its armature and convey to the operator at the distant end of the line the conventional signal.

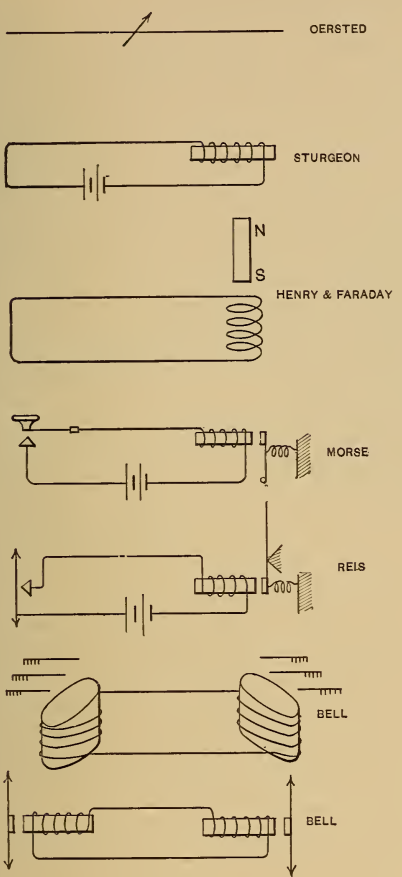
Naturally, the operation of the Morse telegraph suggested the possibility of transmitting the voice itself to a distance, and, indeed, as early as 1854 we find Charles Boursel publishing to the world the possibility of speech transmission in words that have since become historic. He said: "I have asked myself if the spoken word itself could not be transmitted by electricity; in a word, if what was spoken in Vienna may not be heard in Paris. . . . Suppose that a man speaks near a movable disk sufficiently flexible to lose none of the vibrations of the voice; that this disk alternately makes and breaks the connection with a battery; you may have, at a distance, another disk which will simultaneously execute the same vibrations."

Boursel erroneously supposed that the voice could be transmitted by the opening and closing of the circuit, and thus outlined a path of research which science traveled for twenty years, until Bell, by his theory of electric undulations, removed it from the deeply-worn rut. In 1861 Philip Reis, of Frankfort, Germany, apparently following the instruction of Boursel, constructed the first telephone, which comprised as a transmitter a diaphragm, adapted in its vibration to open and close an electric circuit. At the receiving station was placed an electro-magnet, which, by the successive current impulses, sent over the line by the transmitter, caused the magnet to alternately attract and release its armature, to which was secured a thin plate, which, in the vibration of the armature, was moved back and forth, thus beating the air and setting in motion the air particles that conveyed to the ear the sense of sound.

By comparing the telephone of Reis with the telegraph of Morse, it will be observed that the transmitting instruments differ only in that Morse used a key actuated by the hand for opening and closing the circuit, while Reis provided a diaphragm which, for the sake of the analogy, we may consider a key, adapted to be actuated, not by the hand, but by the vocal organs. Again, the only essential difference between the receiving instruments was that Reis had applied to the armature of the Morse instrument a thin plate for the purpose of setting the air particles in motion.

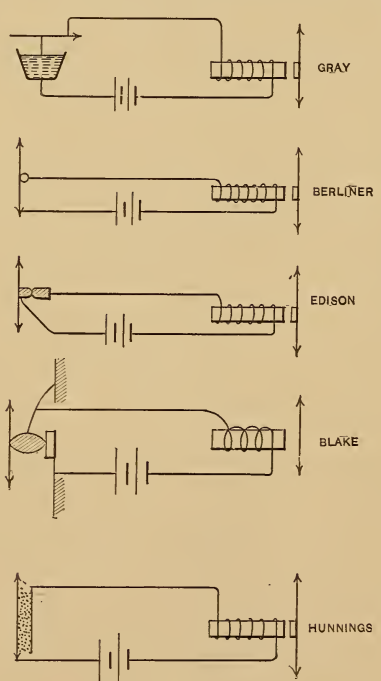
Reis, by opening and closing the circuit, was unable to transmit the complex current undulations upon which we know the transmission of articulate speech to depend, and was able to transmit only simple musical sounds. It has been contended by some that Reis actually transmitted articulate speech by means of his apparatus by causing the contacts to remain continuously in contact, so as to produce an undulatory instead of an intermittent current, and, in fact, with the assistance of our present knowledge, speech may be transmitted by apparatus constructed after that manner. But that Reis himself did not understand the necessity of an undulatory current and did not transmit speech, may be inferred from the fact that in his later apparatus, which was considered by him an improvement upon the former, the construction was such that it was impossible to cause the contacts to remain continuously in contact.

The apparatus of Reis, as Reis used it, was incapable of transmitting articulate speech, since the only effect of each



vibration of the diaphragm was to close the circuit of a battery and send a current impulse over the line. These current impulses being always of the same strength, the vibrating plate of the receiver always produced tones of a given loudness, but as the rate of vibration of the transmitter varied, the rate of vibration of the receiver plate correspondingly varied, the apparatus being thus capable of reproducing the pitch of the sounds. But in complex sounds, and particularly sounds comprising articulate speech, the air particles do not perform a simple to-and-fro movement in constituting the sound, but perform the cycle with more or less complexity, now advancing rapidly, now slower, perhaps receding slightly, and then advancing to complete the stroke, and it is evident that any transmitter that fails to register all of these variations will fail to transmit articulate speech. Since the transmitting diaphragm of the Reis telephone merely registered the completion of the stroke and not the intermediate movements, it was, of course, incapable of transmitting articulate speech.

In the early seventies, Alexander Graham Bell was working upon a harmonic telegraph which, in its essential features, comprised a permanent magnet, opposite the pole of which were located a number of reeds, each adapted to vibrate at a different rate. Encircling the magnet was a coil of wire connected with the coil of a similar instrument at a distance. When one of the reeds was set in vibration, it executed a definite number of vibrations, the number being peculiar to the reed, and the successive approach of its end to the end of the magnet varied the strength of the magnet, thus inducing in the coil a current which, traversing the coil at the receiving station, varied the strength of the magnet which it encircled to cause the successive attraction of a reed having the same characteristic vibration. None of the reeds at the receiving



HISTORICAL TELEPHONE DIAGRAMS.

station thus vibrate except those whose correspondents at the transmitter vibrate, and if a number of the reeds at the transmitting station are caused to vibrate, the corresponding reeds at the receiving station are set in vibration.

Now, since complex sounds may be resolved into a number of superimposed simple sounds, Bell concluded that if the reeds be mounted flexibly enough to vibrate under the influence of sound waves, and are sufficient in number, a person, in speaking against the reeds, would set such reeds, the vibration of which when compounded produce the sound, into vibration, thus causing the corresponding reeds at the receiver to vibrate and reproduce the sound. From this conception of the production of all the simple tones of which the complex tone is composed, Bell, taking a lesson from the human ear, advanced to the conception of a diaphragm which should not have a characteristic vibration to respond to a particular sound, but which should respond to all sounds, and the development of this idea led to the production of the magneto-telephone.

Bell perceived the mathematical requisite for the transmission of speech before he had conceived the means for embodying it in material form. Sir William Thomson, now Lord Kelvin, commenting upon this achievement of Bell, remarked: "We can but admire the hardihood of invention that conceived such very slight means to realize the mathematical conception, that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of the current must vary continuously, as nearly as may be, in simple proportion to the velocity of a particle of air engaged in constituting the sound."

On the day that Bell filed his application for a patent, Elisha Gray filed a caveat in which he showed means for varying the resistance of the circuit to produce the undulatory current. He provided upon the diaphragm a needle which dipped into a cup of acidulated water, and, as the diaphragm vibrated, the needle was caused to approach or recede from an opposed circuit terminal, varying the resistance of the circuit. Bell, in his patent specification, had likewise suggested the employment of means for varying the resistance of the circuit in the production of the undulatory current, and his first successful transmission of speech was accomplished with an instrument embodying this principle. The development of transmitting instruments has been made along this line, while the magneto telephone has been universally employed as a receiving instrument. To Berliner is attributed the invention of a resistance varying telephone, comprising solid electrodes continuously in contact, the varying resistance being accomplished by varying the pressure of contact of the electrodes by the vibration of the diaphragm. Edison conceived the employment of carbon for electrodes, while Blake suggested the mounting of the electrodes individually upon springs, in a manner to prevent the breaking of the circuit. The transmitter has been improved by Hunnings by using granular carbon between a stationary plate and the vibrating diaphragm, thus securing a greater variation of resistance for a given movement of the diaphragm. The Hunnings transmitter, with improvements for preventing the caking of the granular material, marks the highest stage of development of the telephone transmitter.

Thus we see that the development of the telephone has been a gradual one, and has followed a logical course. It furnishes, perhaps, one of the most striking examples of the fact that great inventions do not spontaneously emanate from one mind far in advance of the age, but that each one simply adds his mite to the accumulated knowledge until some one happily supplies that one step which, added to what has gone before, carries the undertaking to success. The discoveries of Oersted and Sturgeon are properly steps in the march of progress and enabled Bell to make that one step—the discovery of the theory of undulations — which brought the efforts to transmit speech to a successful issue and laid the foundation for the later steps that have spanned continents with the human voice.

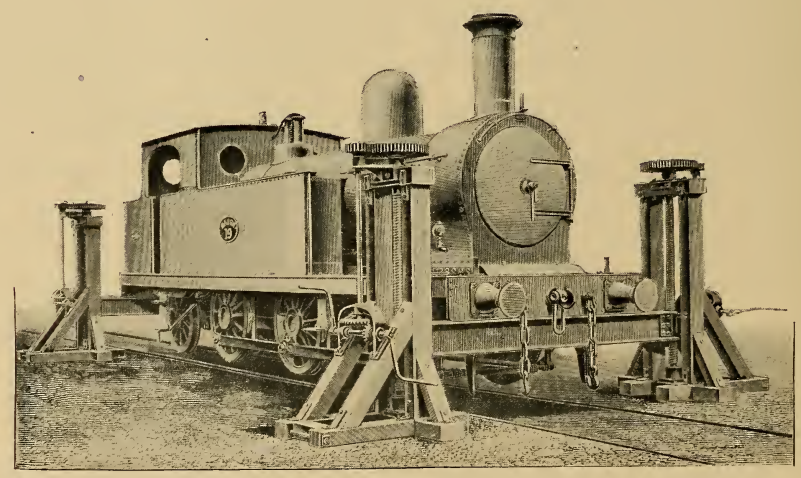
Current Topics.

GEORGE H. CORLISS, during the later years of his life, must have had some satisfaction in knowing that he had furnished the brains for at least two continents of engine builders, since Corliss engines, or rather hyphen-Corliss engines, as they have not inaptly been termed, were even then, as they are now, found almost everywhere in the United States and in European countries. On the European continent especially, nearly every little machine shop built a Corliss engine, and often with a valve motion so complex as to be quite beyond the comprehension of an ordinary mechanic. The changes that were made from Corliss's original ideas seemed, in fact, infinite, commencing sometimes at one end of the valve motion, and sometimes at the other. Even in its simplest form, however, the Corliss gear, as found in the original engines of the great builder, has been criticized on more than one occasion as being "trappy," and when, therefore, a man added to it all a bushel of gear wheels, a peck of jamb-nuts and a maze of rock-shafts and connecting links, gaining thereby, mayhap, a quicker valve-closing by a small fraction of a second, the nature of the final mechanism can be more easily imagined than described. Within the past few years several Corliss engines have been brought out in Germany to which this criticism is perfectly applicable. After all, however, even such travesties as these, must have been, in a certain sense, flattering, showing, as they did, how widely had been appropriated some of the leading principles of steam engine design, first enunciated by Corliss in a practical way.

SEVERAL years ago the Mare Island Navy Yard, at San Francisco, was, and possibly may still be, in possession of an ingenious dredging apparatus which was worked by the tidal current of the Mare Island Straits, and performed some very good work at a nominal cost. Mud having collected along the front of the island, and there being no special appropriation for dredging, the following plan was adopted to remove the accumulations: A suitably braced framework, having floats at each end, was furnished at one end with an undershot water wheel about 20 feet in diameter. Spin wheels on the wheel shaft meshed with gears on two drums. These carried double sets of ropes, and between each pair of ropes were placed small buckets. At the other end of the raft were corresponding loose pulleys ar-

ranged so as to admit of being submerged and dropped into the mud below. The endless ropes from the drums passed around these pulleys. The tidal current, in driving the water which caused the drums to revolve and moved the endless ropes with their buckets, so that these were passed down into the mud, were filled, and then passed out to the end near the water wheel. Before reaching this position they met the swiftly moving current, which washed the mud from them and carried it off to settle in some less objectionable place. The work was carried on very satisfactorily, and the cost of construction and maintenance of the operating plant was comparatively slight.

A VERY handy piece of apparatus for locomotive repair shops in which there is no overhead crane of sufficient strength to lift an engine bodily into the air is that shown on this page. It is made by the Atlas Works, of Glasgow, Scotland, and according to The London Engineer, from which the illustration has been reproduced, it is quite portable, as the cross girders can be disconnected and the whole outfit stowed compactly for transportation. The manner of operation is simple enough and a glance at the little sketch will make it quite clear.



LOCOMOTIVE LIFTING TACKLE.

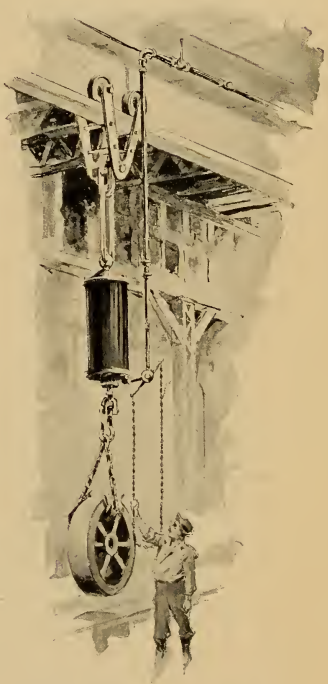
EVERYONE who has had occasion to determine the area of an irregularly shaped surface by the well known method of ordinates knows what a tedious process it is, giving, at its best, only approximately correct figures. It is all the more interesting, therefore, to recall that about a dozen years ago Dr. Charles E. Emery, then chief engineer of the New York Steam Company, in figuring up the areas of large numbers of steam meter diagrams, followed the very simple plan of cutting from each diagram sheet the area enclosed by the irregular pencil outline, weighing the part so obtained, and from this, knowing the density of the paper, finding the desired area by dividing the first figure by the second. The areas of the diagrams were quite large so that the unavoidable percentage of error came within a readily permissible limit. Substantially the same plan had been proposed, even previous to this, for the determination of the areas of steam engine indicator cards, but since these are comparatively restricted, such errors as, for example, those resulting

from inaccuracy in cutting out the diagrams, became so important as to seriously impair the reliability of the results, and the method, therefore, for this particular purpose, did not favourably commend itself.

Outside of the engineering profession, in determining the areas of hides, for example, which certainly are irregular enough in outline, the same system has for years been regularly followed and is still in current use. In still another direction has a modification of it been applied, Mr. J. M. Swank, secretary of the American Iron and Steel Association, having, some years ago, made use of it in determining the geographical centre of total production of the iron and steel industries of the United States. In one of his census reports Mr. Swank explained that this geographical centre of production was the point at which equilibrium would be established were the country taken as a plain surface, itself without weight, but capable of sustaining weight, and loaded with its production of iron and steel, each ton exerting pressure on the pivot point directly proportioned to its distance from it. These several applications of the same principle, as can readily be seen, have the advantages of giving rapidly, and with reasonable accuracy, results which, by the ordinary methods of calculation, would call for considerable amounts of both time and labour.

Ice from electricity was one of several promises recently extended by one of the electric companies in the United States to a number of specially invited guests. Electric heating and cooking, electric forging and electric piano playing were all down on the list of attractions offered, but the making of ice in an electrical way seemed likely to be of pre-eminent interest. True, it was, after all, the regular matter-of-fact process, carried out with one of the well-known makes of ammonia compression machines, but the latter, instead of being driven by a steam engine in the usual way, was connected with an electric motor which furnished the necessary power. It simply afforded another illustration of the rapidly extending field of electric motor applications and certainly demonstrated the making of ice by electricity, though perhaps somewhat differently than may have been expected by those who attended the exhibition.

Machine shop use of compressed air has been growing rapidly of late and a varied service is now being regularly performed by compressed air applances which, not a great while ago, were decidedly exceptional. Compressed air shop hoists, perhaps more than any other similar class of apparatus, have come into favour and are extensively employed over lathes, planers, drill presses and other tools, greatly facilitating the handling of pieces of work too heavy to be lifted without some special contrivance. Some of these hoists are permanent fixtures ; others, like the one shown in the annexed sketch, are suspended from trolleys running on overhead rails, and can be readily shifted about from one point to another as occasion may require, taking their supply of air through flexible hose connections, and being thus available for miscellaneons hoisting service, loading and unloading freight and the like. In one large railroad shop in the western part of the



A COMPRESSED AIR HOIST.

United States, small hoisting cylinders of the kind here shown, are scattered promiscuously about and save an immense amount of manual labor in lifting and handling materials at the different machines. They consist of 10-inch wrought iron pipe, not bored, but simply rattled, and afterwards still further smoothed by pressing a mandrel through them. The air valves for the cylinders are conveniently worked by a regulating lever and chain.

MR. E. S. BARNES, of Rochester, Mich., some time ago designed and built the small steam inspection car of which an illustration is given on this page, and with which some quite noteworthy results have been achieved. The whole outfit, car and engine complete, weighs only about 250 lbs., and Mr. Barnes writes that it has carried a heavy man besides himself, and, moreover, hauled a Sheffield velocipede car behind, with another man aboard, maintaining, with all this, a speed of 10 miles an hour. The car, as the illustration shows, is of the three-wheeled type. The engine is vertical, with a cylinder 2 $\frac{3}{16}$ in. in diameter and a 3-inch stroke. The driving wheels are 17 in. in diameter, and are geared to the engine by means of a sprocket wheel and chain. The sprocket wheel on the engine shaft has 13 teeth, while that on the driving axle has 22 teeth, so that the engine makes $1\frac{9}{13}$ revolution for each revolution of the wheel. This proportion is such that the engine makes about 2000 revolutions per mile. The boiler is of the porcupine type, with a central pipe, 3 in. in diameter and 20 in. long, with seventy-four $\frac{3}{4}$ in. nipples, each $3\frac{1}{2}$ in. long, screwed into the main pipe. These nipples have caps over the ends. The boiler is an exceedingly good steamer. The water tank is 5 in. x 7 in. x 20 in., and will hold enough water to make a run of from 8 to 9 miles with one person, but when an extra man is carried, the distance is reduced to about 5 miles. The piston of the boiler feed-pump is $\frac{3}{8}$ in. in diameter, and has a stroke of 2 in The jacket of the boiler is 11 in. in diameter and 26 in. high to the slope of the hood, and the stack is 4 in. in diameter and 22 in. high. The engine exhausts directly into the stack in order to increase the draft, but the exhaust pipe is so arranged that it can be cut off from the stack and the escaping steam delivered beneath the car. The framing is in imitation of that of the three-wheeled Sheffield velocipede car. The main frame is 12 in. wide between the side rails to accommodate the boiler, which is dropped down between them to within 2 in. of the track, thus bringing the weight down quite low and giving a good balance. The fastest run that has thus far been made with the car is 4 miles in $11\frac{1}{2}$ minutes, which is a trifle more than 20 miles an hour. This was without any wind, but Mr. Barnes tells us that it can be depended upon to make 15 miles an hour on an average. Runs of 4 miles have been repeatedly made without firing.

BARNES' STEAM INSPECTION CAR.

An interesting practical application of an old principle has recently been made in the United States in the shape of what has become known and is put on the market as the "ball nozzle," and for which, as a fire-fighter, some very decided advantages over ordinary

THE BALL NOZZLE.

fire stream nozzles have been claimed, and, in a measure, not without reason. The nozzle has a flaring mouthpiece into which a ball is loosely placed. This ball, notwithstanding the seeming tendency of the issuing jet of water, or other fluid for that matter, to displace it, remains within the mouthpiece, apparently held by some mysterious agency, —by something, for which, as the promoters of the device substantially put it, scientists all over have been unable to account, and the result is a very pretty, and, to many, a puzzling exhibition, giving a funnel-shaped spray of water which ought to be, and no doubt is, an excellent fire extinguisher. Withal, however, it is only proper to say, despite assertions to the contrary, that the nature of what goes on in the ball nozzle is understood very well by scientists, being in perfect accordance with Bernoulli's law for the flow of fluids. The simple, non-mathematical explanation is that the current of water, or other fluid, acts as an ejector or vacuum pump upon any air behind the ball and thus produces a partial vacuum which it cannot fill itself without slowing up. This leaves the atmospheric pressure to hold the ball in and this pressure is ample to do so against the reaction of the stream for the proportions and pressures which are used. Simple enough, one will quite properly say, and yet apparently sufficient to secure no end of free advertising and wondering comment.

Probably no better illustration can be had, even at the present time, of the great importance of free access of air to woodwork as a means of protection against premature decay, than the results of an investigation, conducted a few years ago, into the causes of an accident in an expensive apartment house in one of the principal cities of the United States, in which a portion of one of the upper floors gave way, and, in falling, carried along corresponding sections of the several floors below, landing the whole mass of wreckage in the cellar. It was found that a fortunately unusual system of floor construction had been adopted in the building in question, the spaces between the wooden beams having been filled with ashes, presumably with the view of making a comparatively fire proof structure. Whatever its merits in this respect may have been, there was no question whatever that the mixture of ashes did form a most efficient barrier against the access of air to the timbers, and any moisture that was inherently in them or afterwards found its way to them through the tiling above, had little opportunity of being carried away by any ventilating air currents. The beams simply had to rot, and, that, comparatively quickly. In the subsequent work of reconstruction of the floors, however, good care was taken that they should not again suffer in the same way.

Mill architects, generally, appreciate the preserving influence of free air cir-

culation so thoroughly that they carefully guard against even the painting of any floor beams which are open to the suspicion of imperfect seasoning. Where any moisture is still present in the wood, a coat of paint or tar or anything else impervious to air, ordinarily looked upon as a protective agent, simply prevents this moisture from escaping and thus, instead of guarding against rapid decay, really promotes it to a very material degree. Happily this circumstance is becoming properly recognized and is beginning to receive a due share of attention.

FURTHER illustrations of the evil effects of preventing free access of air to timber have been abundantly supplied by some of the earlier types of armour-clad ships. It was always expected since the first wooden ships were clothed with armour plates that they would speedily decay, and this anticipation was fully realized. The only excuse for the armour plating of some wooden vessels still in existence was the fact that these vessels were already built, or in course of construction, and were of no use at all unless so protected. When once those ships were completed that happened to be on the stocks when ironclads had been proved to be absolute necessities, no other wooden ironclads were laid down. It is the closely fitted wooden backing on the outside and the planking on the inside which prevent the air from getting at the imperfectly seasoned timber of the frames, and this causes the juice of the timber to ferment, and thus induces dry rot. Examination of many wooden ironclads, after comparatively few years of service, resulted in their being almost entirely condemned, while, on the other hand, a large number of old wooden ships, built more than half a century ago, still survive in good condition.

THE idea of centralizing power generation on very large scales in stations in convenient localities, and of distributing the energy broadcast by electrical means is gaining ground everywhere. The coal mining districts have always been looked upon as the ideal places in which to erect such stations, affording, as they would, the primary source of the power—fuel—at minimum cost, and it is quite in the regular order of things, therefore, to find that the latest proposed central station power scheme, this time in Germany, also contemplates one of the coal mining sections, the Hanichen district, as of the kind most likely to yield commercially successful results. Now that so much has been talked about these several projects, it would seem time for something to be done in the way of actual installation and of affording practical proof of the benefits which have been made to appear so alluring on paper.

UTILIZING waste material by transforming it into gas for power, heat and light has, for a long time, been a pet scheme for inventors. Sawdust and general wood débris have been among the waste products successfully operated upon in special gas-making apparatus, and more recently a new and profitable material to be worked over is understood to have been found in Russia in the large heaps of refuse from sunflower seeds, which are there used in great quantities as cattle food and in the production of oil. The husks or shells from these seeds, it seems, proved themselves an exceedingly rich basis for a gas, and the result of experiments which were made has been that at Berruth, in the centre of the sunflower-growing district, a gas-making plant has been put down to utilize the refuse, the intention being to employ the gas for power purposes in a 40 horse-power gas engine. Though detailed particulars of the scheme are lacking, there seems every reason to believe that it is a rational one, from which good results may be expected.

Yours very truly

Philip Hichborn

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AN AMERICAN GRAVITY RAILROAD.

By Charles W. Whiting.

ON SHEPHERD'S CROOK, NEAR CARBONDALE.

"HAVE you been over the 'Gravity' yet?" This is a question often put to strangers at Carbondale, in the heart of the American coal mining regions, by the old residents, and the conversation flows more freely if the answer is in the affirmative. It is always a pleasure to talk over delightful experiences with those who have also enjoyed them, and it certainly is delightful to take a run over the "Gravity" from Carbondale to Honesdale and return.

The "Gravity" here spoken of is the main line, so to speak, of the Delaware and Hudson Canal Company's gravity railroad system, which is one of the oldest railroads in the United States. The railroads first opened in the State of Pennsylvania were constructed for the purpose of connecting the eastern or anthracite coal fields with the canals and natural waterways. It was found impossible to extend these canals to the coal mines; hence, the necessity of some means of land transportation more expeditious and economical than the ordinary earth roads.

The railroad first constructed in the State of Pennsylvania, and the second in the United States, was the Mauch Chunk and Summit Hill, now commonly known as the "Switchback." It was put into use in 1827 to bring the coal from the mines of the Lehigh Company to the Lehigh Canal at Mauch Chunk. The loaded cars ran down by gravity and the empty ones were drawn back by horses. Later, inclined planes were built and the cars were hoisted

CHARLES W. WHITING graduated at Stevens Institute of Technology in 1884, and subsequently served as draughtsman, inspector and engineer of tests for Dr. E. D. Leavitt, the consulting engineer of the Calumet and Hecla Mining Company. For the past year Mr. Whiting has been located at Carbondale and has thus had special facilities for becoming acquainted with the railroad of which he writes.

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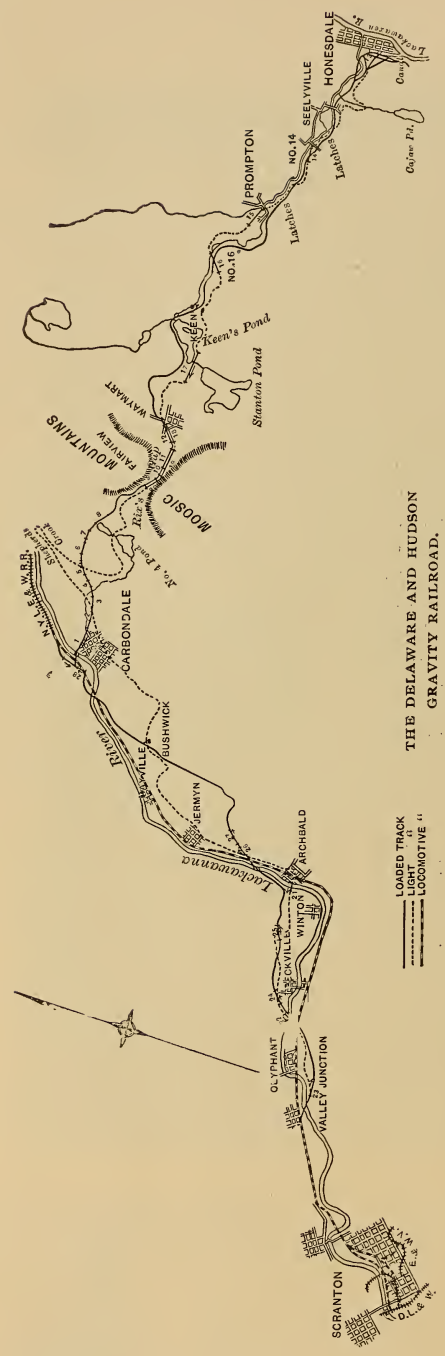


by stationary engines and ran back on other tracks by gravity.

The second railroad built in the State was the Carbondale and Honesdale line, which is now known as the Gravity System of the Delaware and Hudson Canal Company, and which forms the subject of this sketch. This Delaware and Hudson Company was chartered by the New York Legislature on April 23, 1823, to construct a canal and railroad from the Hudson River at Rondout, N. Y., to the coal fields of Pennsylvania. The canal, extending from Rondout to Honesdale, was commenced in July, 1825, and completed in October, 1828; and the railroad, extending from Honesdale into the coal fields, was completed in 1829, the first load of coal having passed over the road on October 9 of that year. J. B. Jervis was then the chief engineer of the road.

In looking over some of the newspapers of that period, we find a few extracts bearing on the road and its construction. The Dundaff Republican, dated Thursday, March 20, 1828, after a short description of the canal, says: "The railway commences at the termination of the canal and runs over Moosic Mountain to the coal mines on the Lackawanna, in length sixteen miles, and overcoming an elevation of eight hundred and fifty-eight feet. Seven locomotive steam engines will be employed, and, on the planes, five stationary engines and brakers."

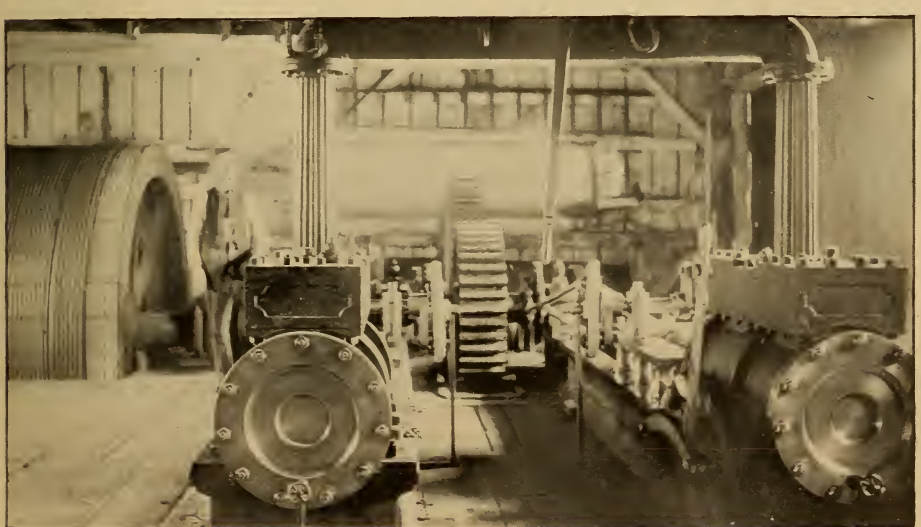
The "brakers" spoken of were a kind of brake mentioned further on. The seven "locomotive steam engines" were not used. The same paper, dated Thursday, November 6, 1828, quotes the following from the "Albany Argus of last week," concerning this company's work: "The canal is complete and will be ready for navigation on the whole line in the course of the ensuing week, and the railroad, from the termination to the coal mines, is in a state of forwardness and will be finished during the present season."

At that time, Carbondale was the western terminus of the road and the mines were close at hand. The route was, generally speaking, what it is

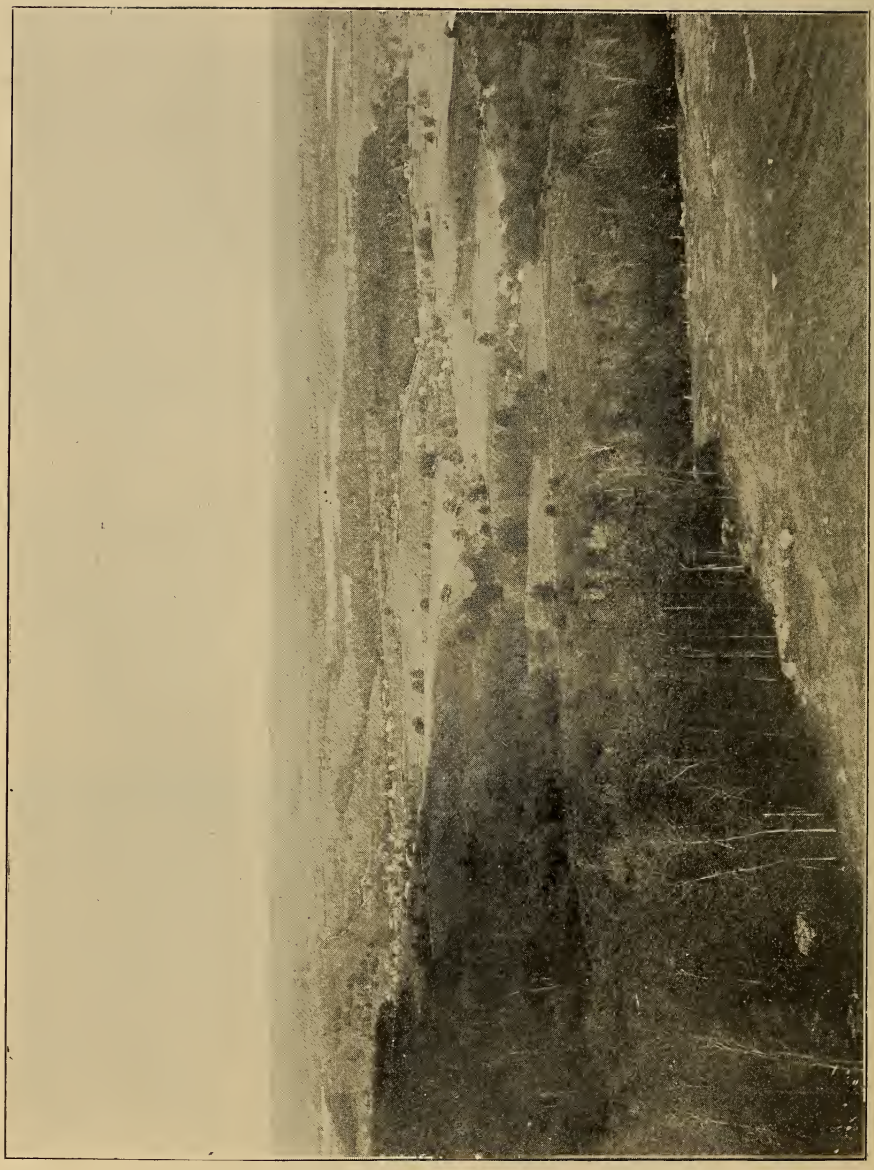
LOOKING UP ONE OF THE PLANES.

now, although many changes and extensions have been made since then. The rails were of flat iron, spiked to longitudinal stringers. They were two and a quarter inches wide by half an inch thick, and were brought from England for the purpose.

Beginning at Carbondale, the road ascended to the top of Moosic Mountain by five planes and intervening "levels," which were not really levels, but down grades, of varying lengths, from the head of one plane to the foot of the next. The planes were numbered consecutively, and we shall speak of them as Old No. 1, Old No. 2, etc., so as



THE HOISTING ENGINES AT THE HEAD OF A PLANE.



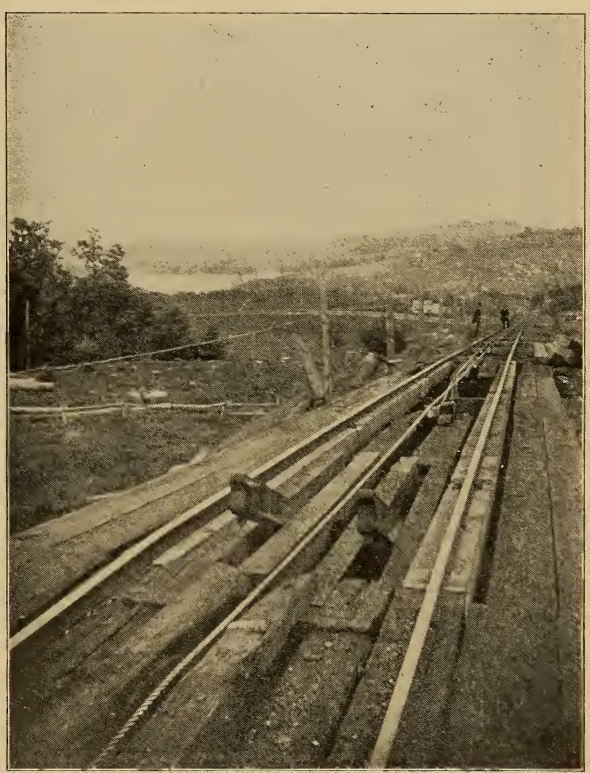
A VIEW DOWN LACKAWANNA VALLEY.

not to confuse them with the present planes. Old No. 1 was at the foot of the mountain at Carbondale. The summit "level" extended from the head of Old No. 5 to the head of Old No. 6, and was about a mile and three-quarters long. From its eastern end, the road descended to Honesdale by three planes and three "levels."

The planes were double, that is, they had two tracks which were operated together, one for the ascending and one for the descending cars. At the head of each plane, there was a pair of iron drums or sheaves, about eight feet in diameter and of nine-inch face. They were placed tandem, like the wheels of a bicycle, and on parallel shafts, and the cable, by means of which the cars were hauled, was wound around them three times, with one end at the head of the plane and the other extending to the foot. The ascending and descending cars, being attached to the two ends of this rope, tended to balance each other and the lack of balance was controlled by the sheaves. One of the sheaves was simply an idler and served to fleet the rope along on the other sheave, so that the three turns could be taken and the increase of friction gained between the main sheave and the rope.

At the planes on the west side of the mountain, Old Nos. 1, 2, 3, 4 and 5, where the ascending cars were loaded and the descending cars were empty, the main sheave was driven by a pair of horizontal engines through a spur-wheel on its shaft and a pinion on the engine shaft. At the planes on the east side, Old Nos. 6, 7 and 8, where the ascending cars were empty and the descending cars were loaded, no motive power was required and the main sheave in this case was controlled by a brake such as is now used for the same purpose.

On the west side, where the hoisting was done, there was trouble from slipping of the rope. As will be seen, the rope really had only three half-turns by which to take hold, for the other three halves were on the idler and therefore of no use. This slipping was very severe in the early days of manilla ropes, especially in the winter when ice could accumulate on them, and a sort of clamp was arranged by which the rope could be taken hold of and brought to rest. This, of course, only prevented the trip from running away and did not secure the rope from slipping on the sheave. The sheaves were then altered slightly. A flange, with a groove around the outside of its circumference, was bolted to each sheave, and in this groove an endless rope was run around the two



AT THE TOP OF A GRADE.

HAULING UP COAL CARS.

sheaves. This was made very tight and was called a "tightening" rope. It was, however, a driving rope to drive the idler and thereby give more active friction to the hoisting rope. This device was quite successful.

There are now only two pairs of these sheaves in use on the road, although the same idea in an improved shape has been used for hoisting engines in various parts of the country up to the present day.

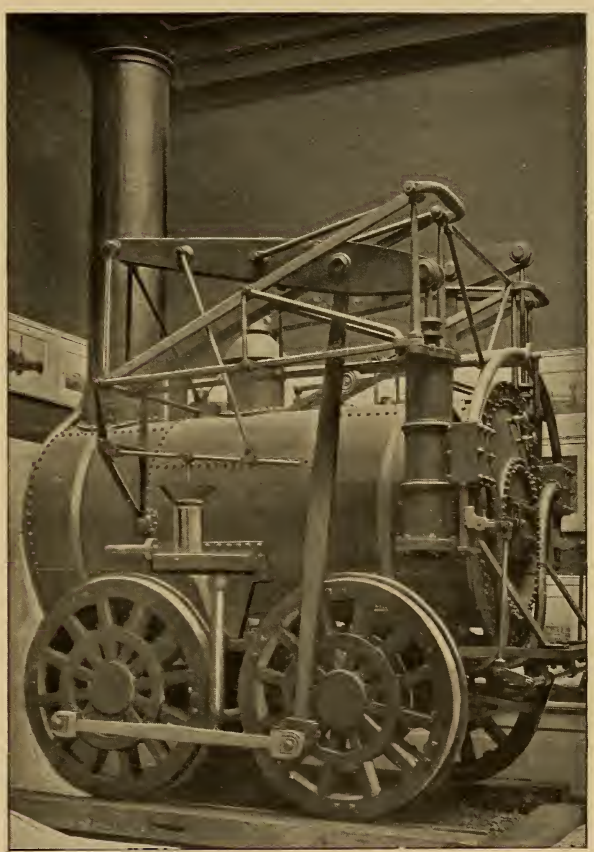
In the earliest days of the road, long chains were used to haul the cars, but, being awkward to handle and costly to repair, they were soon replaced by manilla ropes seven inches in circumference, overlaid with other ropes three-eighths of an inch in diameter and covered with coal tar. They were so treated to protect them against wear and weather, and yet they were taken indoors every Saturday night and brought out again on Monday morning.

On the "levels" the grade was in favor of the loaded cars, the empty ones being drawn back by horses. From the foot of Old No. 7 the "level" was six miles long to the head of Old No. 8. The road here was single tracked with sidings or turnouts, descending at a grade of forty-four feet to the mile, sufficient for the running of loaded cars by gravity, the empties being returned by horses. Each horse drew four coal cars and a horse car on which it rode back. From the foot of Old No. 8 to Honesdale, nearly four miles, the grade

in favour of the loaded cars being but twenty-six feet to the mile, horses were used both ways, five cars in either direction being a train. It was the intention to use locomotives on this part of the road, but after a trial, the idea was abandoned. The road, however, has the distinction of having run the first locomotive in America, the "Stourbridge Lion," named after the town of Stourbridge, England, where it was built, and the face of a lion which adorned the front of the boiler. It was turned out in 1828 by Foster, Rastrick & Co., under the direction of the late Horatio Allen.

Before the road was opened, Mr. Allen had been a civil engineer on the Carbondale line. He was then sent to England, where locomotives were receiving much attention, with instructions to study the subject and to order three locomotives for the company such as he should deem best. This was before the celebrated trial of the "Rocket" on the Liverpool and Manchester Railway in October, 1829. The other two locomotives which Mr. Allen ordered were built by Messrs. Stephenson & Co., of Newcastle-on-Tyne. The "Stourbridge Lion," however, was the only one given a trial, and this took place on August 8, 1829, on the piece of track above mentioned. Mr. Allen acted as engineer and only passenger. Of the trip he says :

"When the time came, and the steam was of the right pressure and all was ready, I took my position on the platform of the locomotive alone, and, with my hand on the throttle valve handle, said, 'If there is any danger in this ride it is not necessary that the life and limbs of more than one should be subjected to that danger.' The locomotive, having no train behind it, answered at once to the movement of the hand. Soon the straight line was run over, the curve was reached and passed before there was time to think as to its not being passed safely, and soon I was out of sight in the three miles ride alone in the woods of Pennsylvania. I had never run a locomotive or any other engine before. I have never run one since."



THE STOURBRIDGE LION, THE FIRST LOCOMOTIVE TO TURN A WHEEL IN AMERICA.

From this we would infer that the trial was a success, but it appears not to have been, for some reason or other, for the locomotive was abandoned then and there. It is now in Washington in

possession of the United States Government. The two engines contracted for with Messrs. Stephenson & Co. were made by them and on substantially the same plans that were embodied in the famous "Rocket." They were shipped to New York and, for a time, were stored in a warehouse on the east side of the city, where they were exhibited to the public. They were never sent to the company's road and it is not known what became of them.

TIGHTENING SHEAVE AT THE FOOT OF A PLANE.

In 1842-45, under the direction of James Archbald, who succeeded Mr. Jervis as chief engineer, the entire location of the road from Carbondale to the summit, with the exception of plane Old No. 1, was changed. The number of planes remained the same, as well as the former summit and summit level. The original road was then followed to the head of Old No. 8; but it and the remainder of the old track to Honesdale were abandoned and the present loaded track was built between these points, on a descending grade of forty-four feet to the mile, thus utilizing the fall of Old No. 8 and making one continuous "level" from the foot of Old No. 7 to Honesdale, a distance of ten miles.

The present empty or "light" track, with a few deviations, was also built from Honesdale to Waymart, that is, the foot of Old No. 7. This necessitated the building of several new planes, those now known as Nos. 13, 14, 15 and 16, but it gave a separate road for each class of cars and so facilitated the handling of them. Water was used as the motive power on the new planes when practicable, that is, on Nos. 14, 15 and 16, the wheels being at the foot. During the same time, the road was extended southwest to Archbald, and in 1856 the present planes and "levels," from the foot of No. 1 to the head of No. 10, were commenced. This arrangement employed eight planes up the mountain from Carbondale to the summit, and all of the planes were renumbered as they are at present.

About this time, too, steam was substituted for water power at the planes using water wheels. In 1859 the road was extended southwest to within a mile of Scranton, the motive power between the terminus and the first plane, No. 23, being locomotives. This portion of the road is now occupied by the standard gauge locomotive road, a third rail accommodating the gravity cars, which are of a narrow gauge. At the same time also the strapiron

rails were replaced by the modern tee rails.

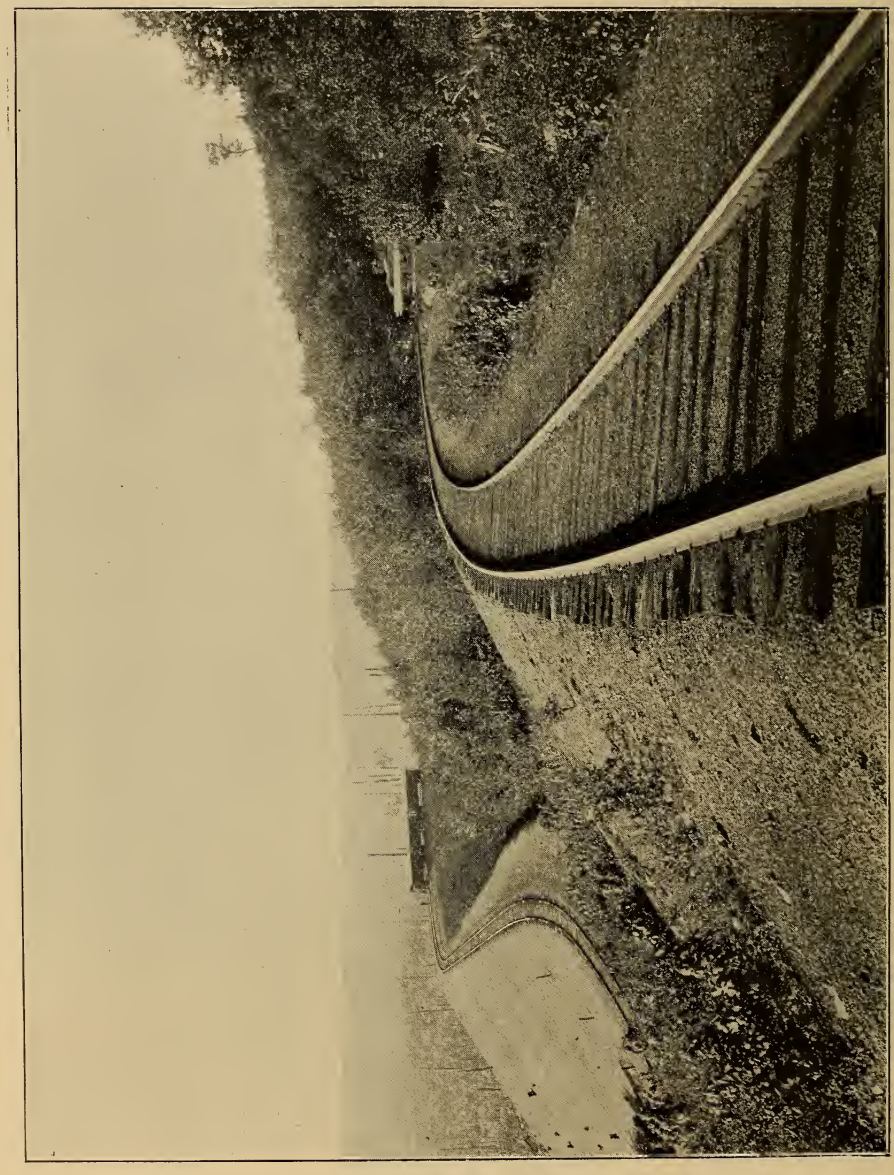
In 1866 the new "light" track planes were commenced at Waymart, under the direction of the late Mr. Manville, and the immediately succeeding years saw the building of the present "light" track down the mountain from the summit "level" to Carbondale. This was completed in 1869, and the double tracks on planes Nos. 1 to 8, inclusive, were then abandoned. This "light" track is one continuous down grade, about fourteen miles in length. It winds in and out among the hills, now running along precipitous banks and now darting into the little valleys or ravines. In a general direction, it skirts along the west side of the mountain, running north, then turns abruptly and runs south. To make this turn, it was necessary to cut into the mountain and then run out on an embankment. This part of the road is called the Shepherd's Crook. The crook or loop measures about four hundred feet in diameter, and the track returns to within ninety feet of itself. The distance around the loop is two thousand feet. This "light" track was built to give a separate and independent track for the two kinds of cars, as were also the new planes Nos. 18, 19 and 20 above mentioned.

DOWN THE VALLEY.

ANOTHER VIEW ON SHEPHERD'S CROOK.

With the old method of operating the road, considerable time was lost at the planes in waiting for cars. The loaded cars had to wait until there were empty ones to be hauled and vice versa. No tail rope was used in those days, and cars were necessary at each end of the rope, not only to take down the descending end, but also to keep the ascending end from whipping about.

The first impression that one gets in taking a trip over the line is that it is not a pleasure road, but a business affair, and a very active one too. The fact is that passenger cars were not put on the road until 1877, the first passenger train running over the road on April 5



SHEPHERD'S CROOK AGAIN.

of that year. At the present time, however, passenger trains, consisting of three or four coaches, run regularly on a schedule, six each way, daily, except on Sunday. Taking one of these trains on a hot summer day, when open cars are used, a most delightful trip can be had.

Leaving the station at Carbondale, on a bell wire which leads up the plane to the engine house, and then makes us fast to the rope. This he does with a sling, a piece of chain five feet long with a hook on each end. One hook engages with a link in the forward end of the car and the other with one of several links in the wire rope as it comes along. Of the two ropes mentioned,

AT THE HEAD OF A PLANE.

the start is very gradual as we crawl away towards the foot of No. 1 plane. At this point there is a man waiting for us and for the coal cars as they come along. It is his duty to signal to the head of the plane, where the hoisting engines are, and to attach the trains or trips to one of the two ropes which run up the plane between the rails. As we come to rest, he gives the signal by pulling one is the hoisting rope and the other is a tail rope. The hoisting rope extends from the links where we take hold and to which it is secured by a rope socket, up the plane to the drum of the hoisting engines. Here the end is made fast by passing it through a hole in one end of the drum and lashing it to the drum shaft. At the other end of the drum, is another hoisting rope, secured

APPROACHING THE FOOT OF A PLANE.

in the same way. This rope, however, is wound up on the drum, all but enough of it to run to the "knuckle," where it is also fastened to a set of links. From these links, then, is the tail rope running down the plane to the foot, where it goes under ground around a tightening sheave and back to the links where we are.

The hoisting ropes are kept in good condition, and when they show signs of wear by the breaking of the individual wire strands, they are taken off the hoisting service and used as tail ropes. These tail ropes answer two purposes. They bring down to the foot of the plane the empty end of the hoisting rope and also balance the hoisting rope, so that, as far as the ropes are concerned, the load on the engines is uniform and consists only of the friction of the ropes on the planes. The ropes are one and a quarter inches in diameter and are made of iron. They rest on cast-iron carrying sheaves, ten inches in diameter, and about twenty or thirty feet apart along the plane.

But now we are moving, and, as the car assumes the inclination of the plane, we find it more comfortable to lounge back in our seats. The angle is not unpleasant, being only one in twelve from the horizontal. We are hoisted up the plane at a speed of about twenty miles an hour. The coal is handled in the same manner, five cars of five tons capacity each making a "trip." Of these cars one has a brake for controlling it and its companions as they run down grade on the "levels" and on the "light" track on the west side of the mountain.

As we pass the "knuckle," that is the head of the plane, a brakeman, who is on our car, unhooks the sling, while

we and the rope are still in motion, and we run along by the force of inertia and gravity. We have come up one hundred and nineteen feet, and traveled fourteen hundred and seventy-nine feet horizontally, and are now running along a "level," having a grade of about fifty feet to the mile, to the foot of No. 2 plane, a distance of sixteen hundred and forty-eight feet. Arrived there, we find another man awaiting us and we are hoisted up No. 2 plane in a similar manner.

Passing the "knuckle," we run along as before on a short "level" to the foot of No. 3 plane. We keep on climbing in this manner until we have reached the head of No. 8 plane, which is the summit of the system and the top of Moosic Mountain. From the foot of No. 1 plane we have come up seven hundred and fifty feet and have traveled a little more than two miles horizontally.

Before going further, let us look into the engine house at the head of this plane and see what sort of machinery has been helping us up the mountain side at such a lively rate. We will find there the same kind and amount, almost exactly, as would be seen at any of the other places that have been passed. There is a pair of 18 x 36-inch horizontal engines, with their cranks at 90 degrees apart on a common shaft. Their valves are ordinary slide valves, each driven by a pair of eccentrics through a link

ALONG THE LINE.

for reversing. On the crank shaft is keyed a pinion which drives a spur wheel keyed to the drum shaft, the reduction being about six to one. The drums are ten feet in diameter and from six to nine feet long, varying with the length of the plane. The boilers are thirty-four inches in diameter and fifty feet long, externally fired, with return tubes.

Taking our car again we run along by gravity, under the control of a hand brake, until we reach Farview, the first regular station. From Farview we are lowered down planes Nos. 9, 10, 11 and 12, reaching Waymart, a drop from Fairview of about five hundred feet. As these planes are only for lowering the trips, they are, of course, not fitted with hoisting engines, but with the brakes previously mentioned. These consist, in the first place, of a drum about ten feet in diameter, upon which the ropes wind and unwind. At one end of the drum is a spur wheel, slightly larger in diameter, which gears with and drives a pinion, about two feet in diameter, keyed to a shaft. This shaft carries a fan and a brake wheel. The fan is twelve feet in diameter and has eight blades. It serves as a drag to the motion of the drum. The brake wheel is encircled by a wrought-iron band, made fast to some part of the frame, but so arranged that it can be tightened about the brake wheel by means of a lever. The latter is controlled by the brakeman in the head-house.

From Waymart to Honesdale, a distance of ten miles, there is one continuous down grade of about forty-four feet to the mile, and the ride over this is most enjoyable. Returning, plane No. 13 takes us up and out of the town immediately. This is the steepest of all the planes, rising about two hundred feet. Then comes one of the pleasantest runs on the road, the "level" from No. 13 to No. 14, something less than three miles long. On the return trip we are hoisted up planes Nos. 14 to 20 inclusive, and run along the intervening "levels" before we reach the summit of the mountain. From Farview to Carbondale we run over the "light" track before spoken of, a continuous down grade of fourteen miles.

The trip is a pleasant and instructive one, and our thanks are due to Superintendent C. R. Manville and Mr. N. L. Moon, his assistant, as well as to other employees of the road, for their kind attention and assistance.

ENGINEERING THREE HUNDRED YEARS AGO.

By W. F. Durfee.

STUDENTS of the history of engineering are always full of regret that we have so little exact information of the mechanical ways and means employed by ancient peoples; but although the totality of our knowledge in this direction is deplorably limited, there is still much more available than is commonly supposed, and he who dives deep enough, and stays down long enough amid the records of ancient methods that have come down to us, is sure to find many things profitable both for amusement and instruction.

One of the most remarkable of the books illustrative of ancient mechanical engineering that we have inherited is entitled, "Le diverse et artificiose machine del Capitano Agustina Ramelli dal Ponte della Tresia. Ingegniero del Christianssisimo Re di Francia et di Pollonia. Nellequali si contengono varii et industriosi Movimenti, degni digrandissima speculatione, per cavarne beneficio infinito in ogni sorte d'operatione; composte in lingua Italiana et Francese. A parigi in casa del'autore, co privilegio del' Re 1588." [The various skillful machines of Captain Augustin Ramelli, from the Bridge of the Tresia; engineer to the most Christian King of France and Poland. Which include many ingenious movements worthy of very great consideration for their utility in all sorts of work. Written in the Italian and French languages. At Paris in the house of the author; by the special consent of the king, 1588.]

Augustin Ramelli was an Italian engineer who was born about the year 1531 at Masanzana, a large suburb of Milan. After having made rapid progress in his studies, especially in mathematics, he served in the imperial army under the orders of Marshal De Marignan, and the courage and genius of which he frequently gave proof quickly obtained for him the rank of captain.

After the death of the Marshal, his protector, in 1555, Ramelli traveled in France and was welcomed by the Duc d' Anjou, afterwards Henry III., who made him his engineer. Severely wounded at the siege of La Rochelle, in 1573, he fell into the hands of the Protestants, but was rescued by the duke, who, during his recovery, took under his protection his son at Paris. When the Prince was called to the kingdom of Poland, his interest and kindness were continued, and when the salic law placed him upon the throne of France he did not neglect Ramelli, but provided him with a position and a liberal pension. Ramelli, in grateful recognition, dedicated to the King the above-named work. In the course of this dedication he says:—"My eyes are not so blind that they do not see the smallness of my intentions, and that they cannot diminish the magnitude and great value of the signal favors which your royal kindness has always extended in my interest. The peculiar affection which you have had for me was demonstrated at La Rochelle, when, in your service, I was severely

W. F. DURFEE is a well-known American civil and mechanical engineer who has had an exceptionally wide field of experience. He designed and built the first works for making Bessemer steel in America, and in these works were cast the ingots from which the first steel rails in that country were rolled.

wounded and taken prisoner, and especially by the particular attention and protection bestowed upon my son at Paris, and, finally, by the very kind letters you deigned to write me from Poland."

Ramelli's book is a large octavo of 338 pages, with an engraved title, a portrait of its author, reproduced on a reduced scale on this page, and 195 copper plates, engraved by Leonard Gualtier in the best style of the time. The plates are surrounded, as is every page of the printed matter, by ornamental

AUGUSTIN RAMELLI.

wood-cut borders, and represent machines intended chiefly for raising water, lifting weights, building bridges, hauling heavy masses, and similar work. The machines were mostly invented by himself. He shows the application of both suction and forcing pumps, the Archimedean screw, various kinds of ballistæ and catapaults, and, finally, a boat, propelled by paddles which are operated by a hand crank. The work is further embellished by numerous wood-cut tail and corner-pieces, and the paper and presswork are very much better than was usual at the time of publication. Altogether this old work on machine construction is remarkable for its contents, its material and its mechanical and artistic execution.

Leaving the personality of Ramelli and the general characteristics of his book, we will now, with the aid of photographic reductions of its illustrative engravings, describe some of his machinery. In Fig. 1 we have a pair of very curiously constructed single-acting pumps, which Ramelli describes as follows: "By means of this kind of machine we raise water from a river, pond, spring or other source of supply to a height in proportion to the power obtainable from a river or canal which is made to turn the wheel A and also the wheel B, which is secured to the upper end of the shaft of A. One-half of this wheel is provided with teeth, which turn the two pinions C and D alternately in opposite directions. On the shaft of these pinions is a screw E, which turns forward and backward with them, and as it engages with the teeth F, by its alternate rotation, raises and lowers, by their curved rods, the pistons in the curved cylinders G H. These pistons draw the water into these cylinders, and, sending it forcibly through their valves, compel it to ascend, by the pipes I and L, to the reservoir M. The valves in these pipes are much like those through which the water enters the curved cylinders, and shut so as to prevent the water from returning."

The general idea of this pump was employed in a steam engine invented and patented about thirty years ago by that veteran American steam engine builder, William Wright. In this engine there was a curved cylinder, of

which the piston was connected to a vibrating sector by curved piston rods passing through stuffing-boxes in each head of the cylinder. To this sector was attached a connecting rod, at a point corresponding to F, in Fig. 1, whose opposite end was coupled to a crank on a shaft which was parallel with the axis of the vibrating sector. Mr. Wright contrived some very ingenious mechanism for boring the curved cylinders and for making the pistons, the circumference of which had to be concave on one side and convex on the other, and to have the concavity and convexity gradually merge into each other on the other two sides.

Ramelli does not state how the pistons of the pump shown in Fig. 1 were made, but, in describing another pump, he says that "the pistons are made of two plates of brass which enclose and bind between them several pieces of leather," and that its "valves are made in the form of a pyramid," which "kind of valve is much the best of the many which have been used for this service, because such valves last much longer and stop the passages through which the water passes very closely." He also says that "pistons are sometimes covered with leather," and in a duplex lift pump, worked in a similar way to that shown in Fig. 1, he recommends that the pistons be so covered "that they may fit the cylinders exactly."

In Fig. 2 we find "a monster machine, able to raise water to a height in proportion to the force of the river or canal which turns the wheel P and the two wheels H and K fixed on its shaft. These wheels have teeth arranged contrary to each other, which turn the lantern Q first one way and then the other. On the shaft of the lantern Q are two screws, R and E, of opposite inclinations, which engage with the worm-wheels G and S which turn forward and backward the lanterns T B secured to their shafts. These lanterns are placed, as shown, on opposite sides of the piston trunk M, and, by means of their teeth gearing with those of the racks, raise and lower the piston in the pump cylinder C, into which the water is drawn through its valves and forced upward through the four tubes within the enveloping tube D, and form a jet d'eau at their upper ends. These tubes have valves which retain the water and prevent its return, and cause its delivery

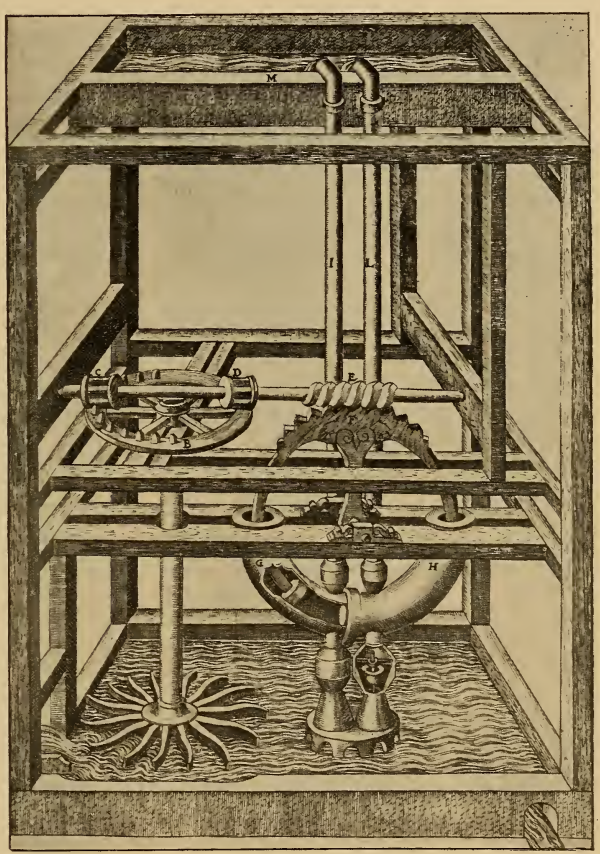


FIG. 1.

into the receiver above, from which it can pass to the place prepared for it. It must be noted that these pumps can be made large or small as desired, but it must be observed that all the proportions must be with reference to the moving force."

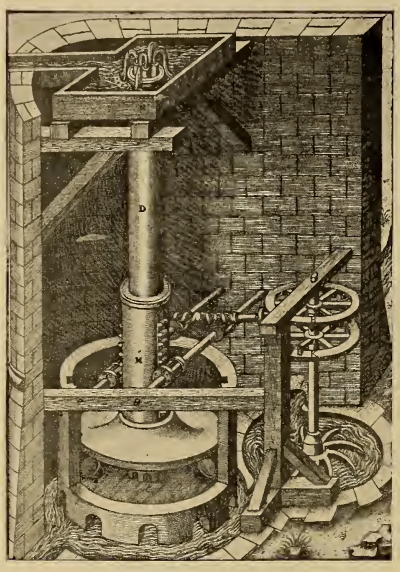


FIG. 2.

In Fig. 3 we have a machine by which we can easily raise water from a well by the aid of a single man, who operates it by turning, by means of a crank, the divided wheel R, in each of the parts of which is an eccentric groove, in which enters one end of a small pin provided with a roller which rolls with the greatest ease when the wheel is turned. This pin and its rollers are attached to the upper end of a small connecting bar M, which, by the rotation of the wheel R, is raised and lowered, as are also the three bars S, H and Z, with which it is connected. These, by their upward and downward movement, actuate the three rods which have the pistons of the three pumps T, F and X attached to their lower ends. The first raises the water into the tank B; the second, into that marked P, and the third, and last, into the receptacle at the top of the well, from which it flows through a pipe into the vase K.

We are told that Fig. 4 is a "machine intended for raising water from a very deep well, with great ease by the efforts of one man who operates it by turning the circular toothed rack around the well, by means of a handle attached to it and by the aid of the rollers below it. The teeth of this rack engage with those of the lantern H, which is connected with, and turns another, lantern R on the upper end of its shaft. This lantern engages the teeth of the wheel N, which is united to and turns the lantern S. To a rope, passing over and around this last lantern, are attached two buckets, and by the above described machinery they are made to descend

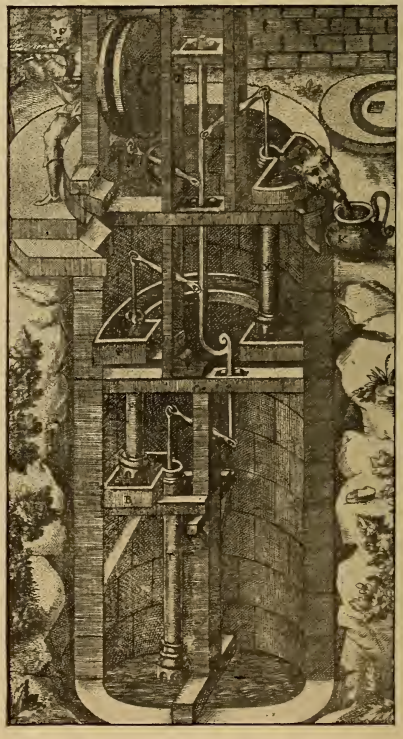


FIG. 3.

and ascend in the well alternately, and raise the water to its top, the circular rack being turned first one way and then the other, as can readily be seen in the engraving. It is advisable

that on the rim of the well there be put a circle of iron or other metal, well smoothed opposite the circular rack, in order that it may turn with greater ease."

This suggestion of an iron gear and the curb for the rim of the well, is evidence that cast-iron was used in machinery at that time. The construction of the spring hook to which the bucket is suspended is evidently quite similar to hooks made at the present day.

Fig. 5 represents "a machine, by the operation of which one man can, with great ease, draw water from a very deep well. This the man does by turning a crank (like that of a drill), which turns the wheel A, placed below the surface of the ground, and on the same shaft with the lantern B, which, at the same time, turns the toothed wheel C. On the shaft of this is a drum which turns with it. This drum is enwrapped by a rope which passes under the pulley F, and makes six or seven turns around the wheel E, above the well. By this means the lantern G, on the same shaft, is turned. Around this lantern is wound the rope to which the bucket H is attached, and by which it is raised to the top of the well, all of which is clearly understood from the engraving." It will be observed that the crank is provided with a roller on its pin; that the wheel A is a fly-wheel; and that the bucket H is suspended by a spring hook.

Fig. 6 shows another water-raising machine. "The man," says Ramelli, "walks in the great wheel Q, which is united with, and turns, a toothed wheel which engages with a lantern. The latter is connected with, and turns, the strong wheel P, which has on its circumference certain teeth, so shaped and proportioned as to enter, as the wheel turns, the rings of the chain which passes over it, and by means of which another wheel K, placed in the well, is turned. This also is a strong wheel, and has teeth similar to those of the wheel P. The wheel in the well is provided with teeth which engage the lantern S. This turns a screw at the lower end of the shaft, and this is in gear with another wheel which turns a wheel within the case Z. This wheel is provided with paddles which force the water up the pipe N, into the reservoir L, from which it descends by another pipe M, and is conducted to the place where it is to be used."

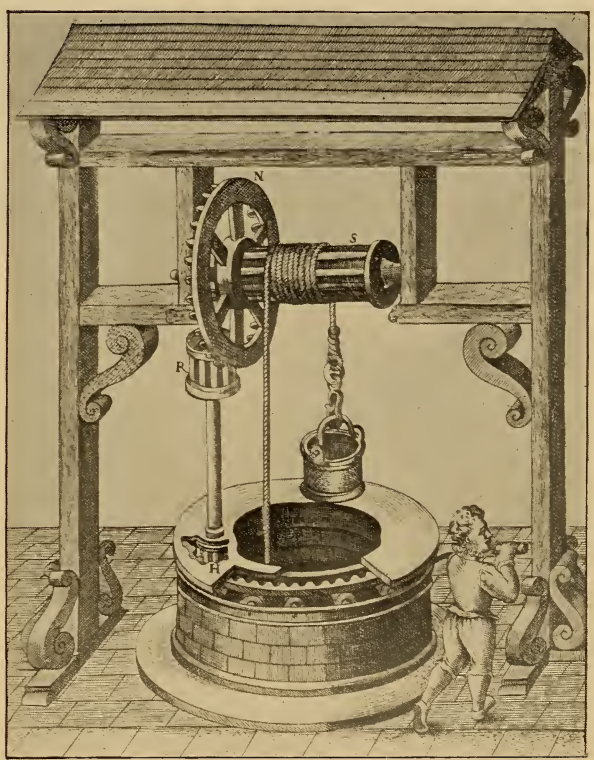


FIG. 4.

Fig. 7 is "a machine somewhat similar to the last, designed to raise water from a deep well by the efforts of a man who walks on the inside of a great

wheel D. This turns in connection with another, much smaller, wheel F, whose teeth engage the pins of the lantern G, which is connected and turns with the crank H. To this is attached a short connecting rod, which is also coupled to a pin in the strong wheel L, above the well. By means of the crank an alternating movement is communicated to the wheel L, which, by means of a chain connection, is communicated to another similar wheel within the well. In this chain is a block, turning on two pins, and pierced by a round hole, in which enters the round end of a lever arm, which is fastened to the rock-shaft M. To this are also secured two shorter arms, whose outer ends are coupled to connecting rods operating the pistons of the two pumps N and P.

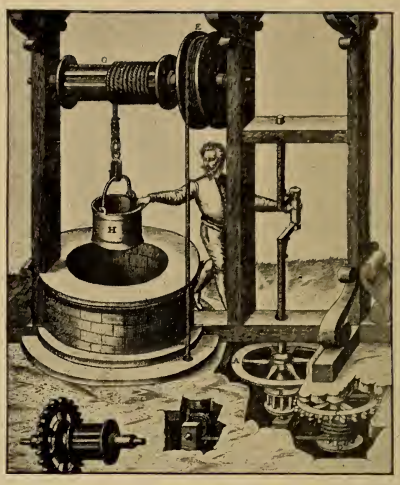


FIG. 5.

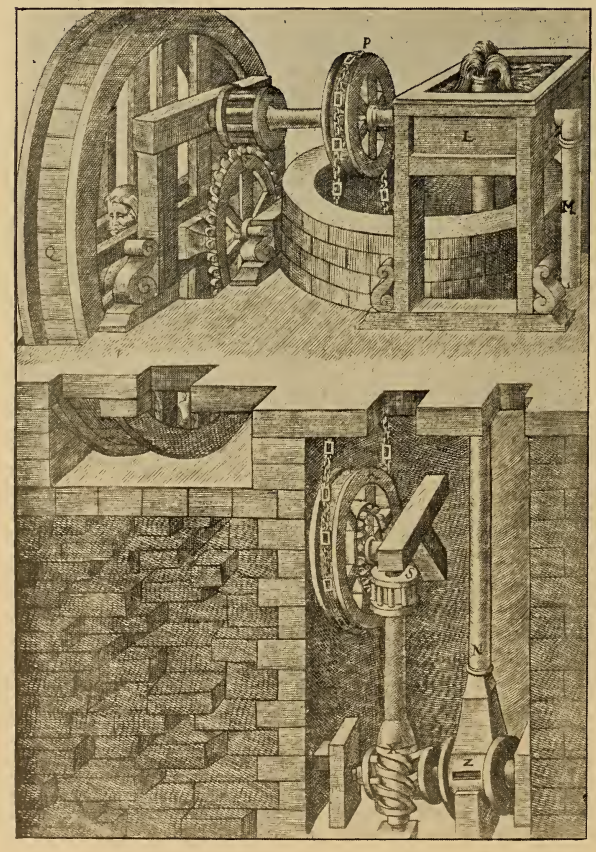


FIG. 6.

"These pumps are placed under the water, which enters them at their tops, and their pistons are so constructed that the water is forced downward; and, alternately, they drive it into the box R, also under the water. The valves of these pumps must be so made as to prevent the water going backward, and always to permit its being forced into the box R, by the alternate movement of the pistons, which compel it to rise through the pipe T into the reservoir S, from which it passes by another pipe Q, to the place where it is needed."

In this machine Ramelli has substituted for a long rigid connecting rod, the peculiarly ingenious chain connection,—a device which might have been profitably employed in many cases in modern times where more ponderous, expensive, and less effective means have been used.

Fig. 8 is a machine by which "the water of a river

is raised to a great height without being subject to pressure. The great wheel A, when turned by the force of the current, raises water by the little boxes around its circumference, into the first reservoir B, and, at the same time, turns the two lanterns C and D, which are fastened to its shaft. These lanterns have pins only on one-half of their circumferences, the one contrary to the other, as will be seen in the picture. These lanterns engage the teeth of the two bars E and F, and raise and lower them, one after the other, by the aid of the chain attached to their upper ends. This chain passes over the pulleys G and H, and supports the bars, which, by their alternate movement, raise and depress the boxes with their gutters, by means of pins attached to the boxes and which enter slots made in the bars.

"The gutters, together with their boxes, M, N, O, P, Q, R, S, T, are supported on a post by pins, about which they move. The first box M, by the depression of the bar E, takes the water from the tank, and by the raising of this bar and the lowering of the other bar F, the water is carried by the gutter into the second box N, and by the movement of the second, into the third, and thence into the fourth box, from which it issues into the upper reservoir. From this it descends by a convenient pipe and is carried away for use."

Of the machine shown in Fig. 9, Ramelli says:—"By the use of this machine we are able to easily remove water from docks, pits, foundations and similar places by the force of a river whose current turns the wheel M. This has on its shaft the artifice seen in the drawing, which enters the slots of the two levers B, D, and, as the shaft turns, raises and lowers them alternately. In conjunction with them, by means of two connecting rods, having eyes at each end, the two rock-shafts F, Q operate the several pumps. These are under the water, which enters them at their

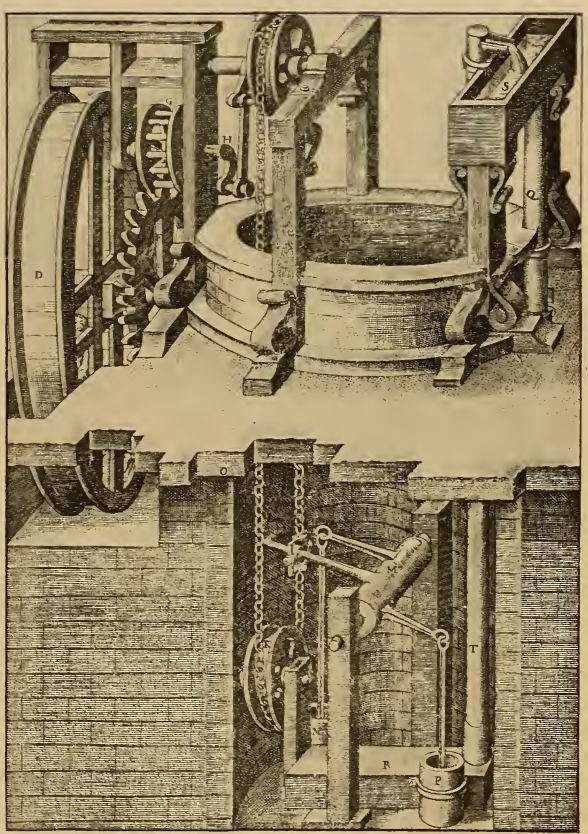


FIG. 7.

tops, and is forced by the descent of the pistons into the four chests M, V, G, Y, which are also under water. The valves of these pumps are like those already described, and the water in the chests, being subjected to the pressure of that which is constantly forced in by the pistons, is compelled to mount by the four pipes Z, X, S, T, by which it is thrown into the river."

It will be seen that the action of the roller cranks in the slots of the levers

gives them a differential movement quite similar to that which has often been used in recent years on small planers and shaping machines.

Fig. 10 represents "another machine for raising water from docks and foundations by means of a river whose current turns the wheel P and the crank O fastened to its shaft. This crank is coupled to a small connecting rod which operates the rock-shaft N. The latter has four arms, to which are coupled the four rods which sustain the pistons

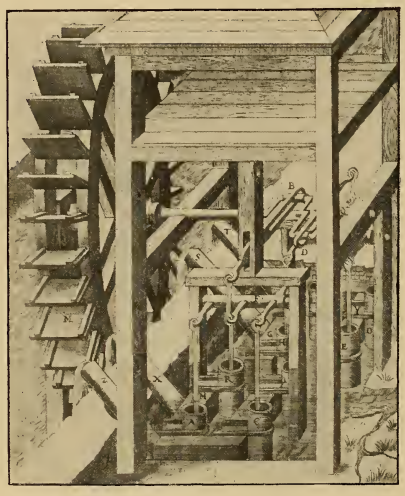


FIG. 9.

rising and falling, alternately, in the four pumps. These are placed below the water, which, entering at their tops, is forced by the pistons into the two chests G and H, also under water, and is thence discharged through the two pipes E and F into the river."

"The object of the invention shown in Fig. 11 is to raise water from foundation pits or similar places by the power of two men. The machine is made of metal, or of some other satisfactory material; but it is very true that when made of metal it is much the best. Other material, although cheaper, will be rougher for the water. The machine has a single cylinder with a partition through its centre and a covering tube C, which encloses the pipe

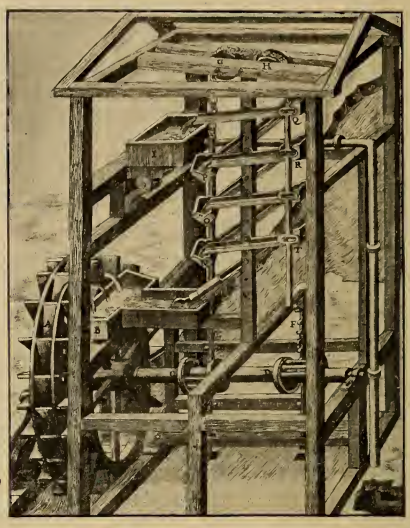


FIG. 8.

marked R. This covering tube is made like that shown at the bottom of the picture, and has two wings at its lower extremity which enter the cylinder at the centre of the partition, which is made so exactly as to form a good joint with the bottom of the tube C. The water enters the bottom of the cylinder, between the wings on the bottom of the tube C and the partition before named. On each side, at the top of the covering tube C, are fastened bars by which the two men turn it within the cylinder,

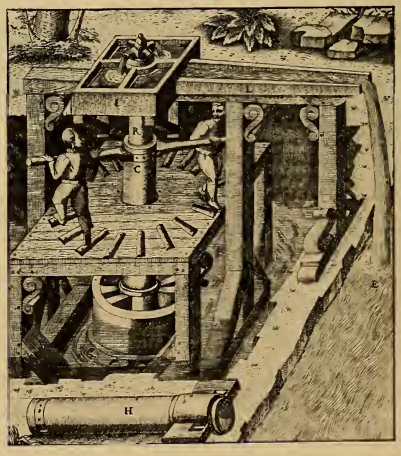


FIG. 11.

first one way and then the other, by which movement the water is forced, by the wings, up the four pipes within the tube R, into the reservoir I, from which it is discharged by the spout L."

Of Fig. 12, Ramelli says that "this machine is designed for the draining of water from docks or foundations by the power of two men, who turn the two cranks of an eccentric wheel within the covering cylinder A. The latter is made of metal or other suitable material, closed and well fastened by screws. It has but one aperture for the entrance of water, and is firm and immovable. When the water enters the cylinder, it is forced around by the movement of the wheel, and its four sliding pieces (which move easily back and forth as required) continually through the tube C."

FIG. 12.

Fig. 13, we are informed, "is a machine by which men can easily remove, with great speed, water from the foundation of a pier or similar structure. In order to commence the work, an enclosure of piles, enlocked with each other, is made. Around this are placed a number of levers made as shown at K, P, Q, T, each having a certain part grooved in the form of a gutter, and at the end of each a large bucket is attached. When the men raise the levers by means of two poles, attached to them by rings, the buckets are filled with water, and when the men depress the levers, the buckets are emptied into the gutters, and the water runs over the top of the piles into the river. After removing the water by the means aforesaid, the workmen can clean out the mud at their pleasure and lay the foundation. In making such machines it is well to know that they are best adapted for situations where the water is shallow; then, two men with a large bucket are very efficient."

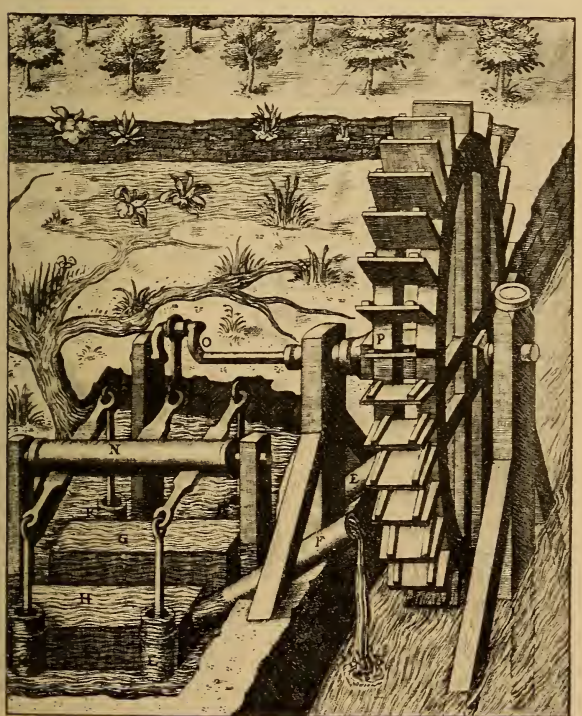


FIG. 10.

Ramelli describes a large variety of corn-mills, one of which is portable, made entirely of iron, and having a conical grooved roller, revolving within an iinternally grooved case. The roller is provided with

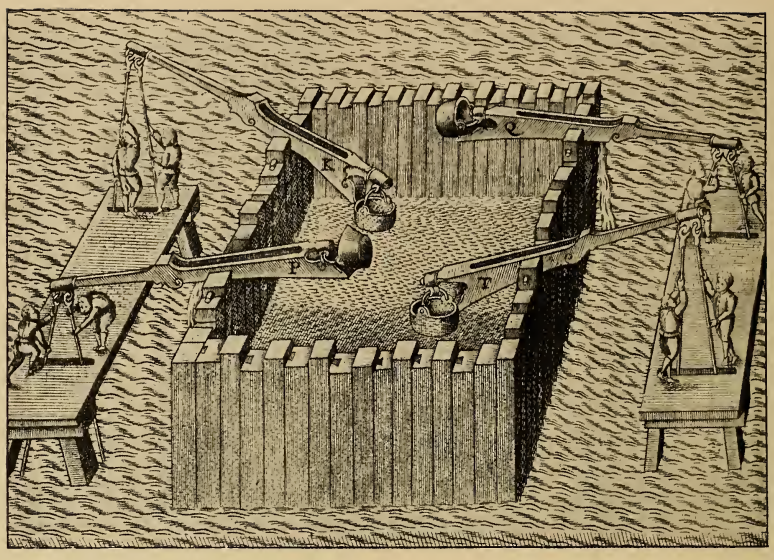


FIG. 13.

adjustments by which the degree of fineness of the meal may be regulated. If Ramelli was really the inventor of one-quarter of the machines illustrated in his most wonderful book, he deserves to be assigned a high rank among the most ingenious and skillful of the mechanicians whose labours have lightened the burdens and increased the happiness of the human race for all coming time.

CORRESPONDENCE SCHOOLS OF ENGINEERING.

By E. P. Roberts, M. E.

E. P. Roberts in 1877 graduated at Stevens Institute of Technology, one of the foremost mechanical engineering schools in the United States. A varied and extensive engineering experience since that time has helped to admirably equip him for the post which he now holds of president of one of the several correspondence schools of technology at present in existence in the United States.

THOUGH the growth of correspondence schools has been rapid, there are, doubtless, still many persons who have never heard of them, or, if they have heard, have doubted their efficiency, or not realized their scope. To these, particularly, some general information respecting such schools may be of interest.

John N. Daniels, the executive secretary of the Chautauqua College, at the Chautauqua Congress at the World's Columbian Exposition, made the point that correspondence instruction can give at least as good results as instruction "in residence." "The strongest argument in favor of correspondence teaching," he remarked, among other things, "is that the student gets help which would otherwise be beyond his reach; for no one studies by correspondence who can go to the college and university for the training he needs. Some students get discouraged and quit work. But the

many press on to the end of their courses and give evidence of the most gratifying results. The fact, however it may be explained, is that correspondence students pass better final examinations, as a rule, than students in residence. But, in considering this fact, we must, of course, bear in mind the nature of the students, their age, determination, and habit of thought." So much for the testimony of one actively engaged and interested in both methods of teaching.

Consider the improbability that correspondence schools would have a steady growth, with the continued endorsement of leading educators, if there did not exist a demand, and if the demand were not satisfactorily supplied. Quack medicine can always be sold by judicious advertising. Some resident schools advertise more than results warrant, and so, also, do some correspondence schools, but the growth of the latter is mostly amongst adults who examine and weigh for themselves. When students obtain other students there must be "good work" on the part of the school, otherwise a student would not be likely to influence his or her friends to take a similar course.

The method of the correspondence engineering school is to prepare special text books covering the engineering features and also such preliminary and allied studies as it deems necessary for a foundation for the engineering line desired. These text books are sent to the student and he is instructed to ask questions on doubtful points and to answer all questions and work out the examples, make drawings and send his results to the school for criticism and helpful suggestions.

Some inquirers are willing to concede that certain studies can be successfully conducted by correspondence, but how about—well, possibly, mechanical drawing? For the answer, all he needs, is to see results. It is often a matter of surprise, even to the instructor himself, to note the improvement of one set of drawings over those preceding, in respect to features formerly criticized. Character of work, accuracy, choice of views, dimensioning, use of tools, all can be criticised. No matter what the subject may be, the instructor who studies correspondence instruction and is also thoroughly acquainted with the subject to be taught can be exceedingly helpful.

The different correspondence schools now in existence differ in the ground covered and in the details of the method, but act on substantially the above basis. Supposing the material to be well prepared, the instructor competent and the student to have sufficient grit to work alone, what is the result? He studies carefully. When he encounters a difficulty he makes an effort to surmount it. If he does not succeed, he obtains assistance which is in such form that it can be studied at the time and then filed for future reference. He works out all the examples, answers all the questions and is criticized on all. If he can write the results and answers accurately and clearly he must be familiar with the subject, and the incidental training in accurate expression is of great and lasting benefit. He grows up with a series of books, corrections and criticism. Each one he mentally digests, part by part, until he obtains a reference library which becomes invaluable. He has individual instruction, more so than in any class, and, nevertheless, is not unduly moulded by the personality of his instructor. Some college students always try to remember what "Prof. ——— said" about the matter and consider it heresy to doubt it.

The preceding paragraphs refer to results which are beneficial. There are also other benefits incidental to the method, such as cheapness, possibility of utilizing to exceptional advantage all spare moments, the fact that change of residence or illness does not prevent going on with the work, the opportunity to study at home, and others which a little thought will suggest to the reader.

President Elliott, of Harvard, says: —"1, Observe; 2, Report accurately; 3, Compare and infer; 4, Express clearly." The student in a correspondence school has such training to an

exceptional degree. No matter by what path the student desires to obtain knowledge, he must remember the trite saying that "there is no royal road to learning." To learn, means work, hard work. The student in a correspondence school must usually work by himself; the instructor cannot inspire him. The students who stick to the studies can, and generally do, surpass those otherwise instructed. This is due both directly and indirectly to the method. But the incidental is a necessary accompaniment. The advantage considered as incidental is that the student who continues his correspondence instruction cultivates habits of self-sacrifice, of self-reliance, of thoroughness and of what may be termed "stick-to-it-iveness."

The reader may advance the suggestion that the latter advantage is one which accompanies all so-called "self-education;" true, but, aside from this feature, self-education is wasteful of time and generally of money, not "up to date," not built on a sufficient foundation or systematically designed and constructed, and the very much-to-be-honoured possessor of it is never quite sure of his knowledge. If the student can go to college, he should go. If he cannot afford the full course, he will be better able to appreciate and obtain more value from a partial course if he has first had a course in a good correspondence school.

Some college graduates make the most enthusiastic students of correspondence courses, though these are primarily for those who cannot go to college. To these they are proving an important help in life, and to have assisted in the development of those who most desire help is not a small pleasure to those to whom the opportunity is given. One school has as a motto, "To earn more, learn more." The expression states a fact, other things being equal, and probably appeals to the dominant thought in the minds of most of the enquirers. If any one is willing to make such sacrifices as are generally possible, a liberal or specialized education is obtainable eventually by correspondence. Students should realize that an education is not obtained by a little work on their part and more on the part of some one else. Listening to lectures, especially so-called popular ones, may be very instructive, but still may not result in really profitable education on the subject. There is no science which has not for its foundation much which is, to many minds, dry and uninteresting. A knowledge of quantities and the science of quantities, mathematics, is always necessary. Such studies necessitate far more time than that taken up by one or two lectures a week. For the above reasons, as well as some only hinted at, students of correspondence schools are drawn from all ranks. Men and women, boys and girls, college graduates, those who can only read and write, men eminent in business or professional life, college instructors, college students, all are represented. No matter what the training and experience of the student may have been, that of his instructor will have been different, and much of value will be imparted.

A correspondence school is like a railway on which all can travel who purchase tickets, but on which there are no Pullman cars. A hand car is furnished and track privileges are granted. Each traveler, moreover, makes out his own time-table, obtains instructions from the train dispatcher at each station, or, when called for between stations, has help up all steep grades; but he must use his own energy throughout the entire trip. Passengers can not help each other actually or by the incentive of competition; but there are also no delays other than those self-made. The management is always on hand, and each passenger always has the right of way.

THE CARE OF STEEL SHIPS.

By Philip Hichborn, Chief Constructor, U. S. N.

THE "ounce-of-prevention" and "pound-of-cure" parable is singularly applicable to the proper maintenance of modern men-of-war, and the experience of the Bureau of Construction and Repair of the United States Navy Department may be of interest to those concerned in steel vessels.

From the moment a craft is commissioned and her complement distributed for her care, odd as it may seem, needed repairs begin and, for a time, this is mainly due to the very newness of the vessel and the careless and unfamiliar handling of much that then is strange to her crew. But the scope of this article is narrowed to the actual service wear and tear and the present provisions taken to minimize deterioration.

A limited understanding of the requirements met in the larger vessels will give an appreciable comprehension of some of the many problems that confront the designer of warships. Restricted to space, equivalent only to the contents of a cube whose edge is not quite 86 feet, a navigable structure of steel, 350 feet long, 69 feet wide and 43 feet deep,—10,200 tons must be so wisely disposed that there shall be machinery,—with coal enough,—capable of driving the ship, at any time, at a rate of over 15 knots; that there shall be 44 guns, ranging from the ponderous 13-inch rifle, with its projectile of 1100 pounds and a powder charge of 50, down to the 6 mm. Gatling that fires a bullet a little heavier than the 1-100 of a pound; and that there shall be ammunition enough, and more, to fight a prolonged action.

The ship must be buoyant, and strong and stable enough to carry the 2695 tons of armor, varying in thickness from 4.15 to 18 inches, which will guard the "vitals," turret the guns and protect their crews, and insure the stability of the craft when exposed to gunfire; must be minutely subdivided for safety's sake into numerous compartments; easily susceptible of thorough and immediate drainage, and must prove a healthful and comfortable housing for 500 busy men, whose duty it will be to run her and maintain her efficient at all times.

Aside from galvanic action, the natural deterioration of steel is always due to oxidation, or rusting, and the preservation of the metal can be best effected by the proper application of some anti-corrosive mixture. Theoretically this seems easy, but practically such is not the case, and even under the best conditions there will be a certain amount of corrosion.

Accessibility is given much consideration in ship designing; but in a structure so complicated as a man-of-war there must be certain parts by nature always difficult of access, and precludingly so when filled with stores and

CHIEF CONSTRUCTOR PHILIP HICHBORN entered the United States Navy in 1869, at the age of thirty, as assistant naval constructor, and six years later became a full constructor. With the advent of the modern naval policy of the United States, in 1881, he was made a member of the first United States Naval Advisory Board, and was prominently associated with all matters affecting the designing of new vessels, as well as the practical and useful remodelling of several old monitors of doubtful utility. In 1883 he was ordered to the Navy Department as assistant chief of the Bureau of Construction and Repair, and from that time to his appointment as Chief Constructor in 1893 he was substantially the foster parent of all that dignified the work of the Bureau. His long term of service was broken only once by his tour of European dockyards, of which an interesting and valuable report was submitted to the United States Navy Department. As a literary worker in the professional line he is best known through his brochure on "Sheathed or Unsheathed Ships."

ammunition. While not especially difficult, the care and preservation of the frames and plating between the inner and outer bottom, is a fatiguing and harassing task; but usually it is these same parts above the inner bottom, in the engine and boiler rooms, where there is generally an accumulation of grease and ashes, and a certain unavoidable amount of water, that are most liable to produce rapid and serious corrosion. Paint can be applied only at irregular intervals, and even then is susceptible of speedy destruction, so that cement has been found to be indispensable and to afford the greatest immunity.

By the careful adjustment of fittings exposed to bilge water, serious trouble has been avoided, and to this end the modern manhole frame, now used in the bilges, has a raised coaming, high enough to keep the cover above the water ordinarily present. Experience, too, shows that no harm to the inside structural material from galvanic action need be feared except from fittings composed entirely, or for the greater part, of copper and constantly in contact with bilge water. A curious instance of the outside of a vessel being injured by a metallic connection with immersed copper was exemplified in the "Bancroft," the steel practice cruiser of the United States Naval Academy. Abnormal corrosion was found on docking, and investigation showed that the cruiser and the "Santee," a coppered wooden vessel, some 90 feet away, were mistakenly moored by chains to a single anchor. Such damage grows with the salinity of the water.

Thorough and ready accessibility, coupled with proper painting and intelligent care, makes the preservation of the coal bunkers an easy matter, even though exposed to excessive wear and tear, and, excepting where paint has been carelessly applied over scale and rust, permitting unchecked corrosion beneath, the main trouble has been confined to the water-tight doors, scuttles and hatches. There the annoyance, for the greater part, has been occasioned by paint-rotted rubber gaskets painted in spite of special inhibition.

The corrosion and rusting of iron and steel is a complicated process, and the rust or scale produced varies with the inducing conditions. The densest or heaviest scale is still much lighter than iron, and is composed largely of oxygen, so that scale an inch thick would consume but ⅓ of an inch of solid metal. The average scale, one inch thick, however, absorbs about ⅙ of an inch of metal, and scale is sometimes found even much lighter.

Moisture initiates rust, and "sweating," or the condensation of the air's humidity upon the colder surface of the steel, is the chief evil to be mitigated on shipboard. The curve in the accompanying diagram shows the maximum weight of moisture which can be contained in a state of vapor, in a cubic foot of air, throughout a range of temperature from 0 to 120 deg. Fah. Deposition varies with the prevalence of increased moisture and the conductivity of the metal.

Where the surface contact is with a poor conductor of heat, that surface may be raised by slow degrees to the temperature of the surrounding air with little or no condensation, and the whole thickness of the material may be gradually heated by the action of the air without reducing the temperature of the latter to the dew point. If the surface exposed to the air be kept always

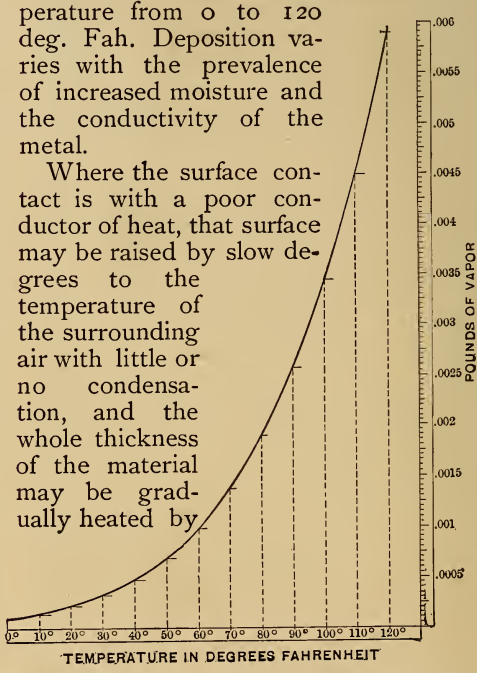


DIAGRAM SHOWING WEIGHT OF VAPOR IN SATURATED AIR AT DIFFERENT TEMPERATURES.

above the dew point of that air, "sweating" cannot take place; and, therefore, something must be done to reduce the natural heat-absorbing qualities of the steel by the application of some non-conducting substance. The service method, as regards structural material, is to apply a coat of adhesive paint against which granulated cork is thrown, the whole being left untouched to dry, after which the cork-faced surface is painted over in the customary way. Unless there be exceptional weather conditions this gives fairly satisfactory results; but the desideratum is some non-conductive composition, which, in addition to the cork now used, could be put on thick enough with a brush to prevent sweating. Ordinary paint is far too good a conductor to answer these requirements. In special cases, such as that of flushing pipes, through which there is a constant circulation of cold water, a thicker non-conducting covering is demanded, and hair-felt lagging, or some similar material, has been used.

First thought would suggest good ventilation as a remedy for local dampness; but, as a matter of fact, the amount of sweating in the magazines and double-bottom spaces has been increased from twenty to fifty times by the admission of fresh air,—of course warmer and humid,—coming in contact with the colder metal of the under-water portions of the vessel. This circumstance was discovered experimentally in certain cases on some new ships where it was thought that imperfect ventilation caused the sweating; the fact was, the ventilation was too good.

The drainage plants of the new ships of the United States Navy have suffered a great deal in service, and more or less extensive and frequent renewals have been required. The purpose of these systems has been to compass thoroughly every compartment of the ship, controlling each by at least one hand pump and one steam pump, while some of the principal compartments have had even more numerous means of exhaust. This aim has resulted in a mass of pipes and valves difficult to keep in order and subject to rapid corrosion. The only way to avoid this trouble and expense will be the adoption of a simpler system, and the elimination of such pipes and valves as practice has shown to be of exceptional use.

In the ventilation system, where the pipes are even more numerous, and the valves many, aside from the natural wear upon the almost constantly active fan engines, there has been but little trouble with the durable galvanized iron pipes. Woodwork has been purposely reduced on the steel vessels to restrict decay and to reduce the possibility of fire and splinters in action, and in some cases linoleum has been substituted for the ordinary wooden decking.

With such auxiliary machinery as steering-gear, windlasses, hoisting engines, etc., experience has shown that, with proper care and the renewal of brasses at reasonable intervals, they give but little trouble. Where needful, efficient and thorough lubrication was lacking, and where the appliances provided were unused, the natural result, in several cases, was failure.

The outside of the ship is the next consideration. The portion above water is usually the best cared-for part of the craft, for it is always in evidence, and if there be corrosion going on it is soon manifested by streaks of rust, and the cause is easily discovered and removed. But such is not the case with the under-water part. There the difficulty doubles. We have to avoid the corrosion of the metal and to remove marine growths, and, all things considered, this part of the vessel has been the greatest annoyance and a most perplexing study. Here, as elsewhere, if the metal be always covered by paint sufficient to keep the water from contact, no damage can be done; but this has been an impossible attainment.

As far as possible, the practice has been to dock, clean and paint steel vessels at least once in six months; and, while without funds to carry on experiments of untried inventions, every paint that, from actual use, gave valua-

Speeds of Vessels with Clean and Foul Bottoms.

Name of Ship.	No. of Days Steaming.		Speed in Knots per Hour.		Consumption of Coal per Day, Tons.		Radius of Action.	
	Clean.	Foul.	Clean.	Foul.	Clean.	Foul.	Clean.	Foul.
Charleston	25.09	14.2	8 8	8.8	30.3	53 4	5,293	2,995
Yorktown	19.7	13.0	9.6	9.2	19.3	29 2	4,358	2,878
Philadelphia	23.4	24.12	11.6	10.0	44.1	42.8	6,506	5,644
San Francisco	18.05	15.58	9.6	9.14	34.8	40.3	4,237	3,419
Bennington	3.58	4.63	7.85	6.20	18.71	27.86	4,058	2,153
Baltimore	24.49	18.30	11.3	11.7	46.7	62.5	6,651	5,144

ble promise, has been more or less tested in service. The results in the naval service have manifested irreconcilable discrepancies, due, no doubt, to the differing conditions of service, and in this particular, naval vessels, with their uncertain movements and dubious docking facilities within their neighborhood, differ from the merchant service, where the conditions and requirements are foreknown, and the best paint can be determined by actual trial, and used year in and year out.

For the prevention of corrosion alone, red lead and white zinc, properly mixed and applied, have given uniformly good results; but the time in dock required to permit this composition to dry is its one objection,—a prohibiting one at times. In the matter of anti-fouling paints, results of experiments have been, if possible, even more contradictory than in the case of anti-corrosive paints; and longer experience will be needed to discover the cause of these discordant effects.

The prevention of a foul bottom is a matter of great importance to the service, both in the light of economy and the maintenance of the unhampered fighting efficiency of the vessels. The table above is graphically conclusive, and, when the cost of coal is considered, the figures become even more impressive.

Experience has shown also that the New York, the Newark and the Detroit, at 10 knots, burn, respectively, 9, 11 and 7 tons more coal a day when foul than when clean. Practice has proved that the various paints and anti-corrosive mixtures give only temporary satisfaction at best, while the use of divers to remove marine growth,—an excellent expedient so far as the propellers, which should be kept smooth and clean, are concerned,—is dangerous to the life of the bottom plating, where they generally remove the protective paint with the cumbering growth.

What then are we to do to assure to the ships, to some extent at least, that independence of docks possessed by the old wooden copper-sheathed vessels, and make them able, at all times, to maintain their designed speeds? The past and growing practice of the present in European navies answers that question. Sheath them with wood and copper this under-water portion. The well-known exfoliation of copper will cause the shedding of any marine accumulation within a brief while after the craft is put in motion, and will maintain the bottom bright and clean so long as the metal remains. The additional cost of sheathing would soon be paid for by the reduction of coal consumption and docking charges, while the uniform efficiency of the vessel would grow correspondingly. The sheathing would give added strength and ease of repair, for ordinary damage to the bottom would be restricted to either the copper or the woodwork.

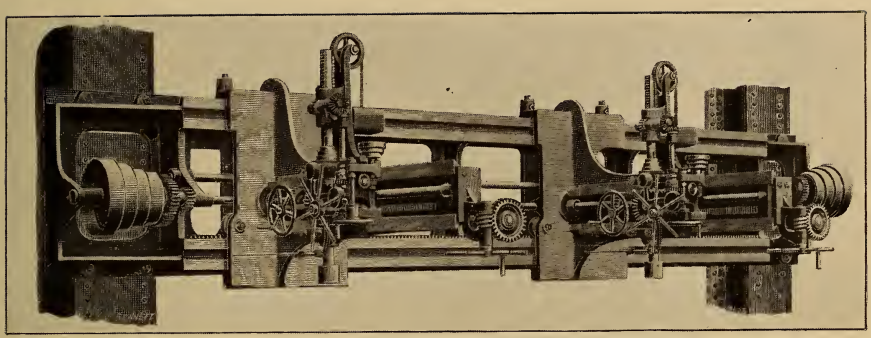
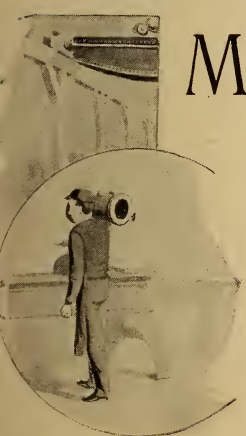


PLATE-DRILLING MACHINE AT THE FAIRFIELD ENGINEERING WORKS, BUILT BY MESSRS. G. & A. HARVEY, GLASGOW, SCOTLAND.

SOME RECENT MACHINE TOOLS.

By George L. Clark.

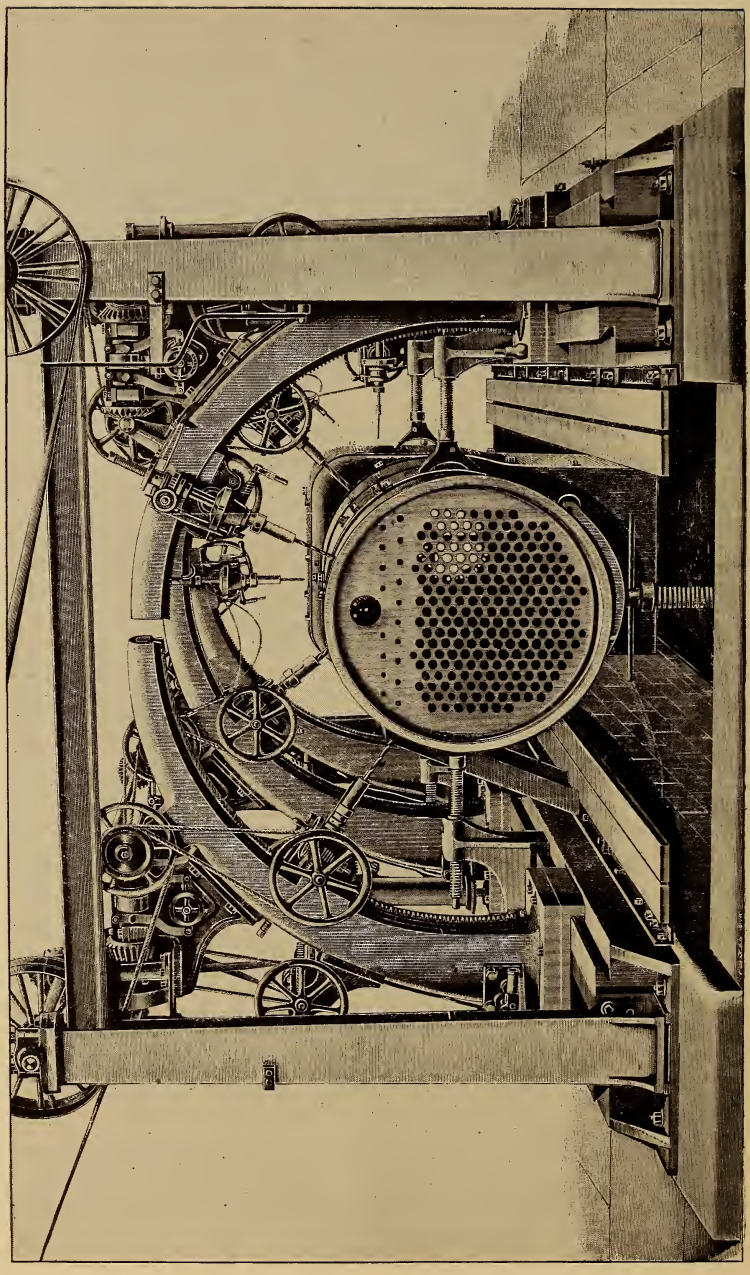
GEORGE L. CLARK has, for several years past, contributed extensively to CASSIER'S MAGAZINE, mainly in the line of new machinery designs, enjoying, as he does, special facilities for keeping in touch with the latest developments. The tools described by him in the present article are representative of some of the most recent types of machines.



MACHINE tool designs have not lagged behind in the general progress of recent years, and where shops still have at work occasional specimens of queerly contrived apparatus, it is certainly not for lack in the market of something better. Every possible want in machine shop practice seems to have been foreseen and met, so that there are now standard and special tools in almost endless number and variety, each designed to add to that excellence of work and economy in production that have become imperative in the race for supremacy in every direction.

To the prospective user, as well as to the builder, of machine tools, the knowledge of what new designs are being brought out is of the first interest and importance,—to the one, as indicating what is available for the improvement of his shop practice, and to the other as a measure of what workers in the same field as himself are doing, each profiting, more or less, by the experience and results of the other. This should sufficiently account for the presentation of the several illustrations of tools in these pages.

Of these the one on the next page represents an interesting example of the large class of multiple drilling machines which, of late years, have come into favour, the one here shown being intended for locomotive boiler work. The rivet holes in the flat portions of such a boiler are readily dealt with in vertical or horizontal drilling machines with single or multiple spindles, but the curved portions, such as the barrel and

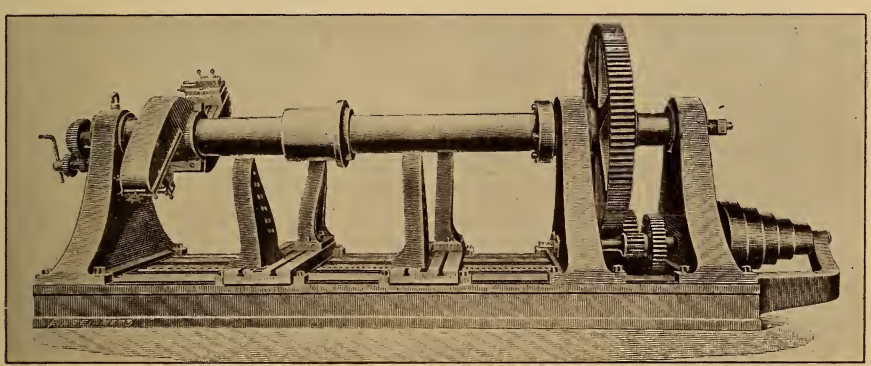


A MULTIPLE DRILL FOR LOCOMOTIVE BOILERS, BUILT BY MESSRS. HULSE & CO., SALFORD, ENGLAND.

flanged corners of the fire-box shell, require special treatment; hence, the peculiar and at once striking features of design in the machine in question. The boiler shell, after being tacked together with a few service bolts, is placed horizontally in the machine and held in position by suitable screw attachments. The upper half is then drilled, and afterward the boiler is turned half-way around and the holes in the remaining portion are drilled, thus completing the work with only one shift of the job. Absolute coincidence of the holes is insured with this method of drilling, a desideratum of which every engineer appreciates the importance.

horizontal lines. Segmental arms surmount the saddles, and are fitted with spindle slides, adjustable radially by curved racks. The spindles are thus made to point always to the axis of the boiler when drilling the horizontal and circular seams of the barrel; but there is yet another adjustment provided for each spindle, namely, a vertical, radial adjustment, enabling the drilling of holes in various planes parallel to one another, as in rectangular fire-boxes, or at angles with one another, as in curved fire-boxes.

Rotary motion is transmitted from the countershaft to the drill spindles by means of belts and bevel gearing,



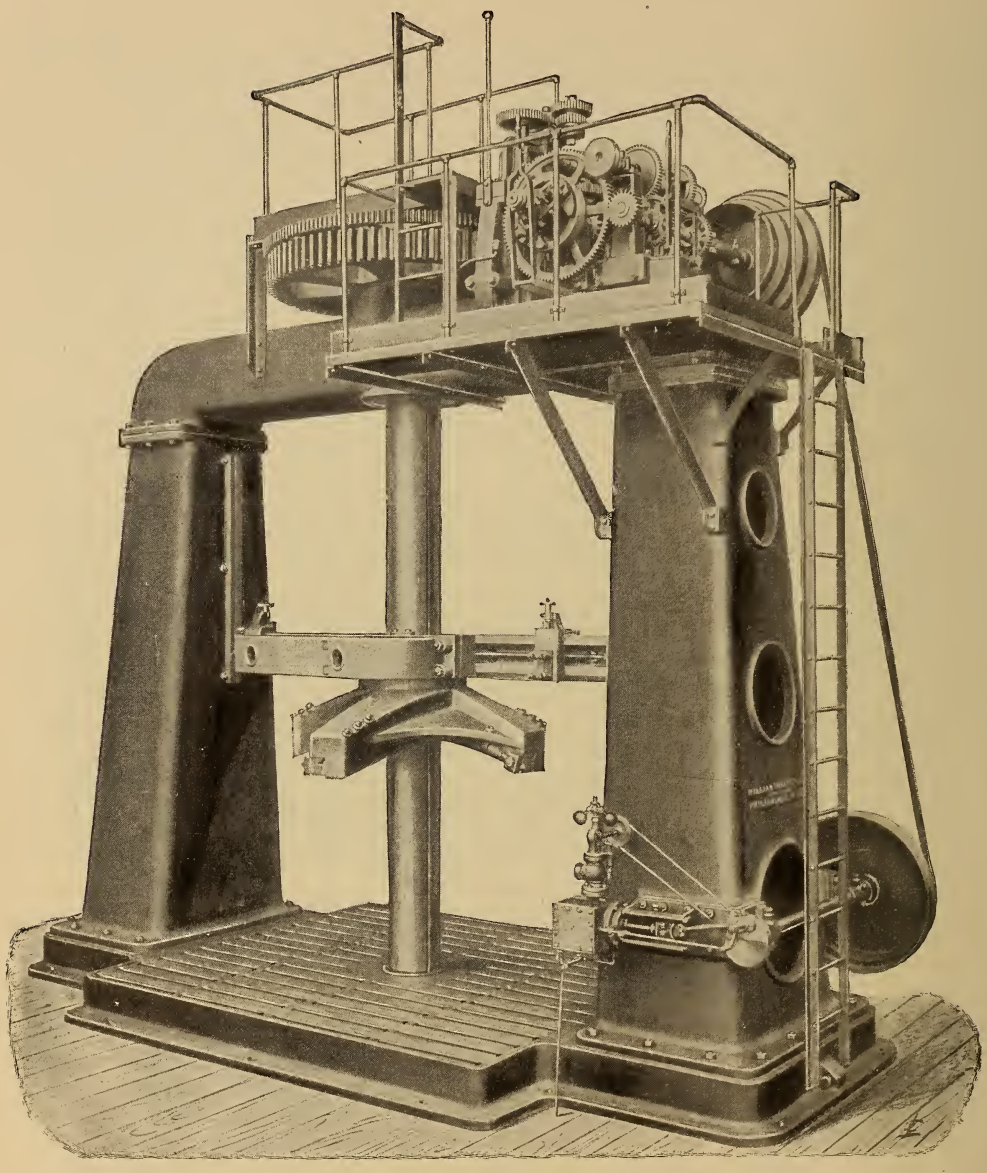
HORIZONTAL CYLINDER BORING MACHINE, BUILT BY MESSRS. GEO. BOOTH & CO., HALIFAX, ENGLAND.

The machine here shown was built last year for the Glasgow Locomotive Works by Messrs. Hulse & Co., of Salford, England, after the designs of Mr. C. M. Davies. It has two horizontal slide beds, placed, respectively, on opposite sides of a pit, with vertical standards carrying the self-contained countershafting which is attached to the ends of each.

In the beds are racks by means of which the several drilling headstocks may be traversed by hand and power in either direction for quickly adjusting the drills in lines parallel with the axes of the boilers. Fitted to the beds are sliding saddles with circular tee slides on their upper surfaces, affording radial adjustment to the drill spindles in

tension apparatus being fitted to each drilling headstock for always keeping the belts tight, and friction apparatus being provided for throwing each spindle in or out of gear independently. Each spindle also has an independent, self-acting feed motion, and a quick hand-traverse in and out. The machine illustrated has six drill spindles, but this number may be varied.

A plate-drilling machine, built by Messrs. G. & A. Harvey, of Glasgow, is shown on the first page of this article, one of its interesting features being that it was designed to be bolted to the shop columns. The bed-plate is a little over 34 feet long over all, the planed portion measuring nearly 29 feet in length, by 4 ft. 7 in. in width. There are two



VERTICAL CYLINDER BORING MACHINE, BUILT BY WILLIAM SELLERS & CO., PHILADELPHIA, PA., U. S. A.

arms, fitted to the bedplate with V's and adjustable anti-friction rollers, and each carries a saddle with a 3-inch steel spindle. Power for motion along the bedplate is taken from an independent driving shaft with friction clutch attachments controlled by the attendant at the saddles.

The drill spindles also are driven by independent shafts, each having a cone and double gearing at the end of the bedplate. The horizontal shafts in the arms are connected to the spindles by spur and bevel wheels working steel clutches, the latter having a quick vertical movement by lever handles so that

the spindles may be made to revolve in either direction, thus adapting the machine to tapping holes and fixing studs. Although, as illustrated, the machine is designed to be bolted to shop columns or walls, it can be supported on independent standards. It is capable of boring over a surface 25 ft. long by 7 ft. broad.

In the line of cylinder boring machines, two designs are shown, one on the page opposite, and the other on page 115, the former being a heavy vertical machine for cylinders from 4 to 9 ft. in diameter and up to 10 ft. long. It consists of a large bedplate carrying two massive uprights, 13 ft. apart, joined at the top by a deep cross-beam which carries the driving and feeding machinery and provides the upper bearing for the boring bar. The latter, which is 16 in. in diameter, runs in a bushing in the cross-beam, and is supported by a step and bearing in the bedplate. It is so arranged that it may be lifted up to clear the work when cylinders are being put into the machine or taken out. In lifting the bar, it passes through the large driving and feed gears without disturbing them, as they are supported by the rotating bushing in which the bar slides.

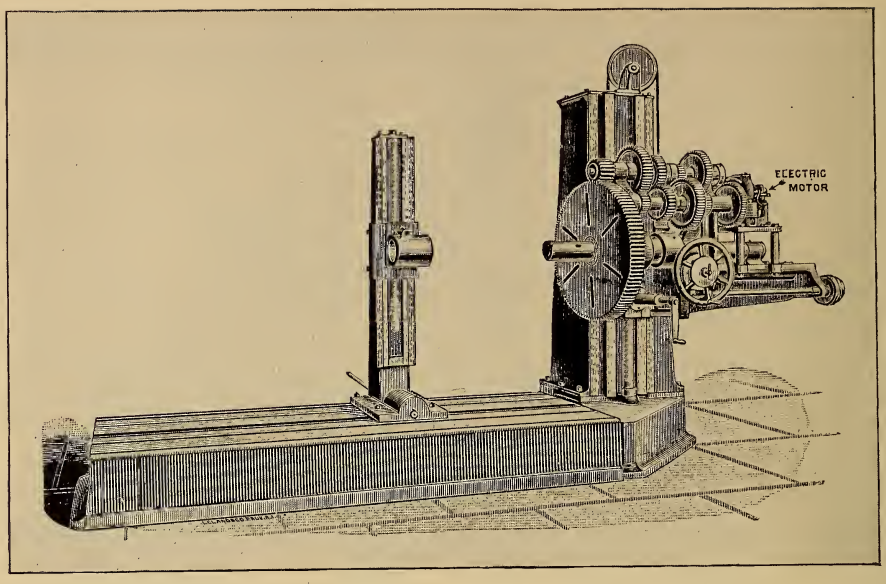
Upon the bar is a moving sleeve, provided with a central flange, and to this sleeve are secured the cutter heads for various sizes of cylinder, and the double facing-rest which is used for turning off flanges of cylinders up to 10 feet in diameter. The traveling sleeve is supported on two feed screws which are provided with a hand adjustment, a power feed, variable from 1-16 in. to about 1⅜ in. per revolution of bar, and a rapid power traverse by means of which the head can be quickly raised or lowered while the bar is standing at rest or rotating in either direction.

The motive power is usually furnished by an 8 x 8-inch engine, bolted to one of the uprights, and carrying a large cone pulley on the end of the crankshaft. This cone is connected by belt to a corresponding cone on the cross-beam, and from this the various movements of the machine are operated. The controlling levers are grouped for convenient manipulation by an operator standing on a platform on the top of the machine.

The cutter heads, of which there are three, are arranged with adjustable tool slides, and are specially designed to bore to the bottoms of cylinders having solid lower heads. They are also arranged so that the same tools can be made to bore in either direction, and in addition to the variations of speed obtainable through the cone pulleys, the adjustable governor of the engine permits still further variations in the driving speed.

The horizontal machine on page 115, built by Messrs. Geo. Booth & Co., of Halifax, is a less pretentious piece of apparatus, being intended for cylinders of from 2 to 5 ft. in diameter. The boring bar is 11 ft. long and 13 in. in diameter, and is fitted with a self-acting sliding block for receiving the various cutter blocks. There is a double-tool surfacing head for facing each end of a cylinder, and this also is rendered self-acting in its feed motion by means of a star wheel. The bedplate measures 16 ft. by 5 ft. 6 in., and is planed on each side so that it can be jointed if required. The cylinders to be machined are held in adjustable V blocks.

Another boring machine, interesting among other things because of the fact that it is driven by an electric motor, is that built by Messrs. Beaman & Smith, of Providence, R. I., and shown on page 118. The spindle head on the upright column is vertically adjustable from 22 in. to 5 ft. above the bedplate. The range of speed makes it possible to bore a 48-in. hole as well as to drill a 1-in. hole and all intermediate sizes. The electric motor runs at 800, 1200 and 1600 revolutionsper minute. The ratios of gearing from motor to spindle are 20, 60, 136 and 408. Opposite the spindle is an outer column for supporting the boring bars. This column carries a small sliding head, which, by suitably graduated strips, can be made to coincide at all times quickly and accurately with the spindle. The column has also a longitudinal adjustment on the bed-



ELECTRICALLY-DRIVEN BORING MACHINE, BUILT BY BEAMAN & SMITH, PROVIDENCE, R. I., U. S. A.

plate, and can be placed from 3 to 10 ft. from the main upright column. This movement, by racks and pinions, can be quickly accomplished.

The spindle head is counterbalanced by a weight in the column and can be conveniently moved up and down the column with a slight amount of power. The thrust of the cutting tool is taken by a ball bearing at the back of the spindle, reducing the friction to a minimum. The machine weighs about 10 tons and stands about 10 feet high and 18 feet long.

Still another boring machine of recent design is that built by the Ingersoll Milling Machine Company, of Rockford, Ill. It is a 60-in. horizontal tool with a 5-in. spindle which has a variable feed of from $\frac{1}{200}$ to $\frac{6}{10}$ in. per revolution. There is also an automatic reversible speed for the cross table, so that the machine can be converted into a milling machine for certain classes of work. The outer bearing in the yoke is hinged, so that the boring bar can be removed without having to slide it through the yoke.

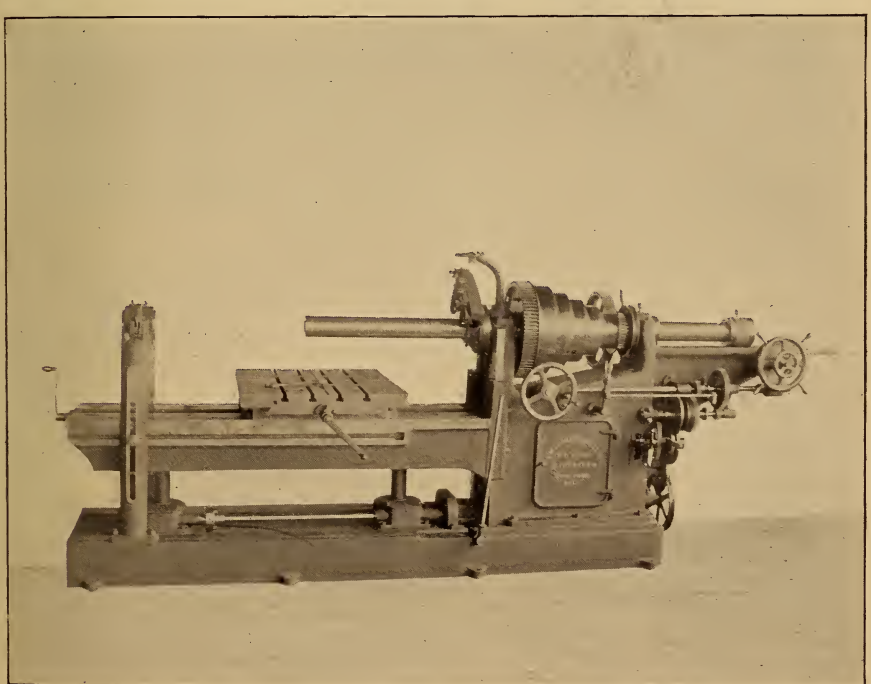
Coming back again to drilling machines, we find a good design of tool of this class in the heavy universal radial drill built by the Bickford Drill & Tool Co., of Cincinnati, O., and shown on page 120. The column, with large, round base, is bolted to the bottom plate, and over this column, with a long bearing on top and bottom, is fitted the outside sleeve which carries the arm. The sleeve rests on the bottom on a large flange, and is fitted with three clamping bolts. The rotating arm, fitted over the sleeve, is of a box form, strongly braced on the top and bottom, and raises and lowers by power. The flange of the sleeve is provided with a roller bearing which allows the arm to swing with perfect freedom. The machines are driven from a cone pulley on the back of the drill, and by means of miter gears through the inside of the column to the top. All sizes are fitted with back gearing. The spindles are counterweighted, have powerful automatic feed and are fitted with a quick return motion. In place of the box table shown in the illustration, a universal tilting table can be furnished. With the head rotating, and the arm revolving around its own axis, it is possible to drill at any angle

and in any direction within the range of the arm.

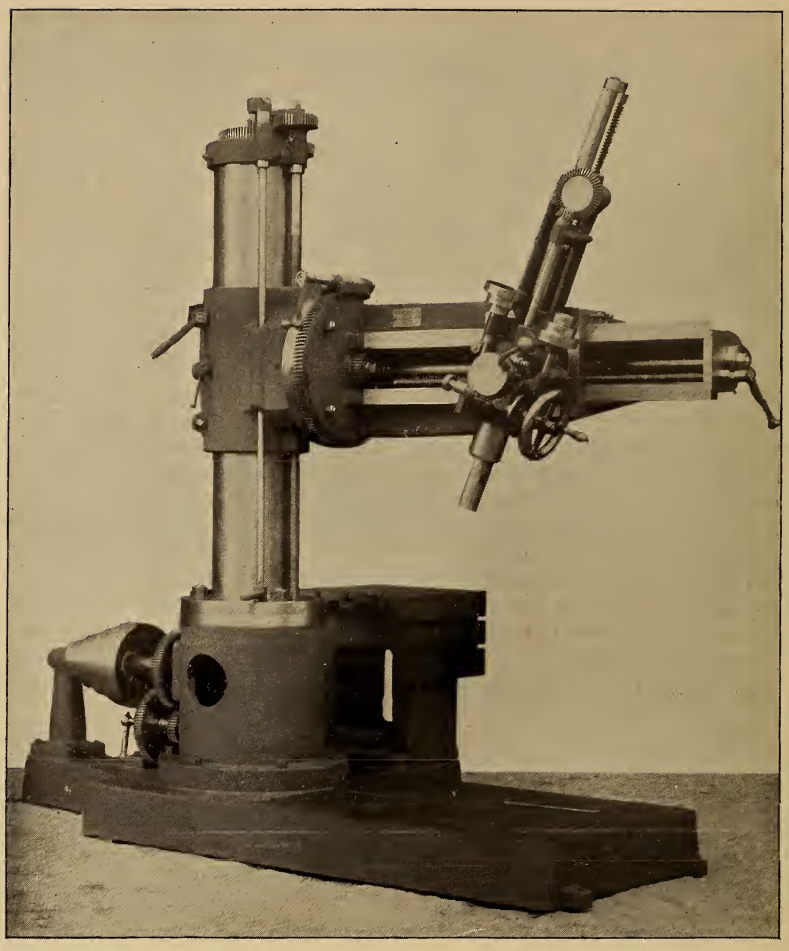
On page 121 is shown an 8-spindle boiler shell drilling machine built by Messrs. Scriven & Co., of Leeds, England, for the Central Marine Engine Works, at West Hartlepool. The machine has two vertical standards on opposite sides of a central turn-table. Each standard has a transverse movement on a slide, and the latter has a movement on a foundation frame towards and from the centre of the table, so as to adjust the drills for boilers of different diameters. Each standard, moreover, carries two cross slides, and each of these carries two drilling spindles. The cross slides have a vertical motion on the standards for adjustment for holes at various heights, and have, also, a swiveling motion by worm gear by which they can be turned completely round, so as to be suited for drilling horizontal ring seams or vertical butt seams as may be required.

The two drilling spindles on each cross slide are carried on two separate independent saddles, and are each provided with independent self-acting feed gear. Each spindle can be swiveled on its saddle so as to point in a truly radial direction from the centre of the boiler. The swiveling of the spindles is regulated by a guide bar, which can be set at any angle to suit the various diameters of boilers. By this means the spindles are adjusted in pitch and to the true radial line by one motion.

Each spindle being completely independent, there is no waiting for other drills to get through, but each proceeds to the next hole as soon as one hole is finished. The main standards can be swiveled so as to bring the spindles into radial line when drilling butt seams which are not exactly opposite each other. The central turn-table, which is carried on a centre-pin and rollers, can be moved around in either direction by power. A driving gear is also provided for the table, so that by fixing a tool holder to one of the standards, it



HORIZONTAL BORING AND MILLING MACHINE, BUILT BY THE INGERSOLL MILLING MACHINE CO., ROCKFORD, ILL., U. S. A.

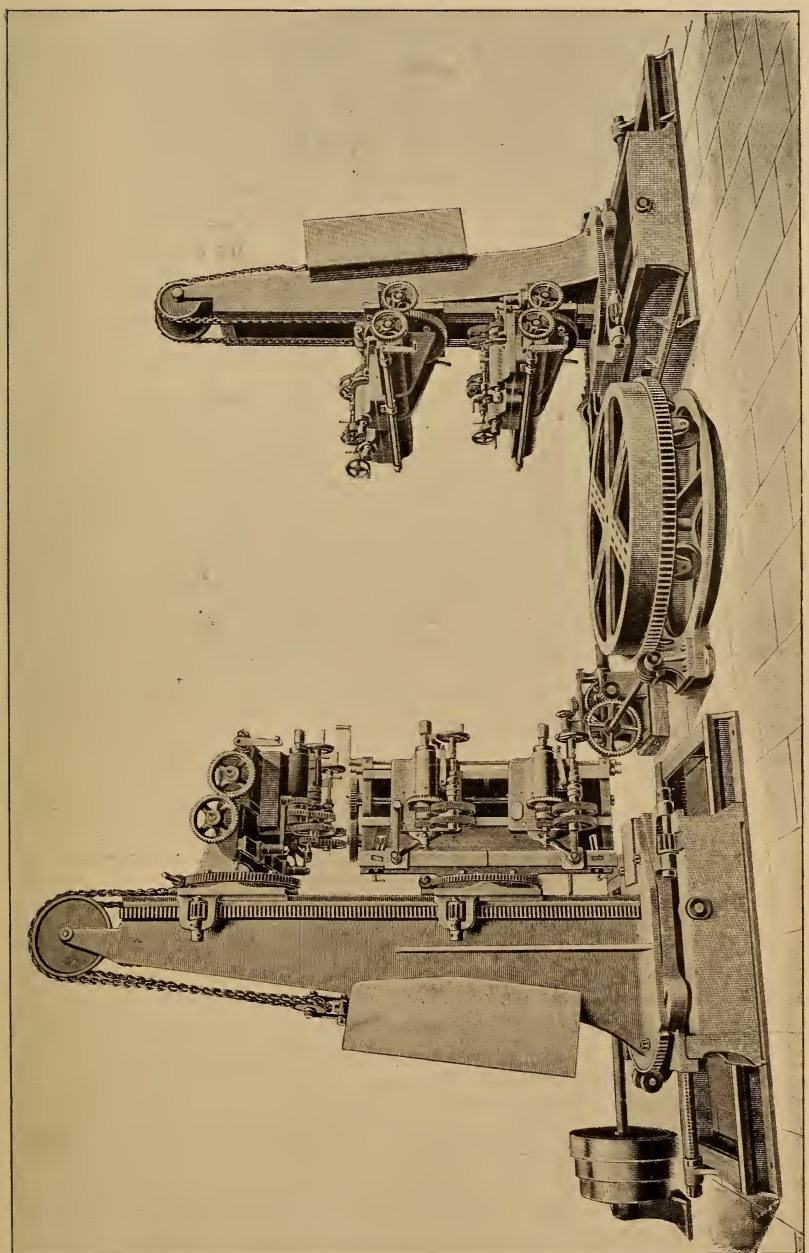


UNIVERSAL RADIAL DRILL, BUILT BY THE BICKFORD DRILL & TOOL CO., CINCINNATI, O., U. S. A.

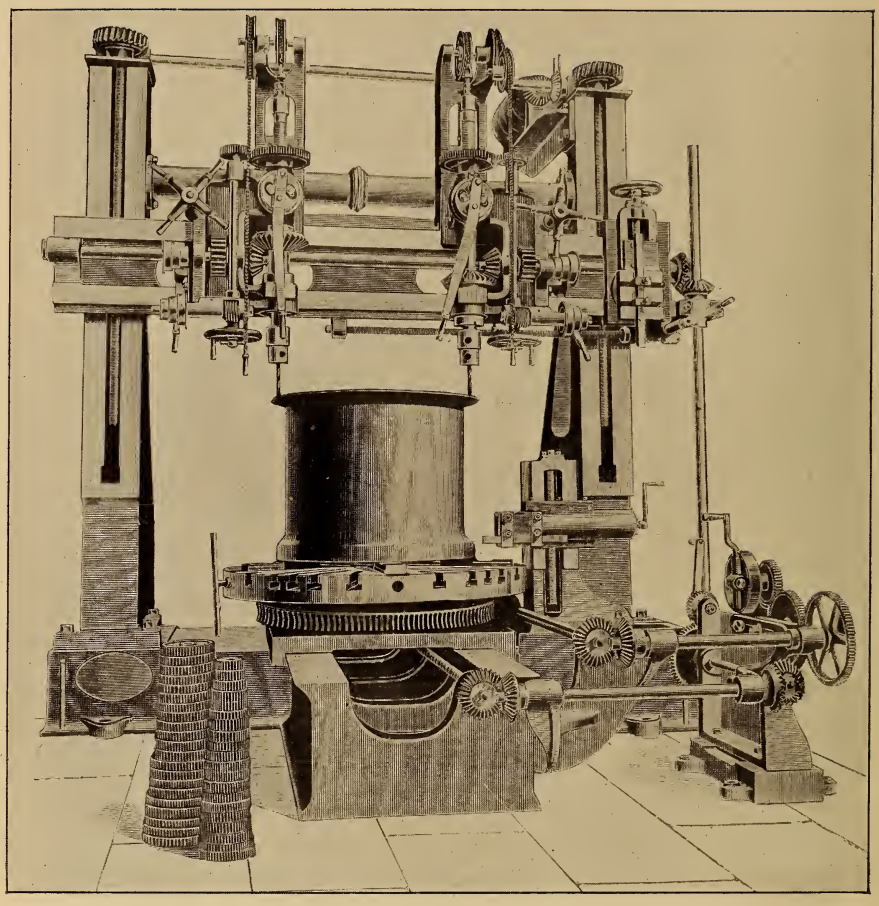
can be used for facing up flanged end plates and other similar work.

A special tool for turning, boring and drilling boiler flue ends, built by Messrs. Rushworth & Co., of Sowerby Bridge, England, for the well-known firm of Messrs. Davey, Paxman & Co., of Colchester, is shown on page 122. The machine will admit a job 8 ft. 2 in. in height, while the height from the top of the chuck to the under side of the spindles when the cross slide is in the top position is 6 ft. 4 in.

The cross slide is arranged to rise and fall by worm gearing worked from belt-driven pulleys at the top of the right-hand standard in the illustration. On this cross slide are two heads for drilling, arranged to rise and fall by power by worm gear, as shown in the illustration, to move by rack and pinion and by hand wheel. The spindles are of steel, 3 in. in diameter, and of 10-in. range, and are balanced, so that when the nuts, which are of gun-metal, in two parts, are released by the lever in front, the spindles return quickly. The minimum distance from center to center of holes which can be bored is 10½ in. The drills can be run separately or together, a steel clutch being arranged on each



BOILER SHELL DRILLING MACHINE, BUILT BY MESSRS. SCRIVEN & CO. LEEDS, ENGLAND.



BOILER END TURNING, BORING AND DRILLING MACHINE, BUILT BY MESSRS. RUSHWORTH & CO., SOWERBY BRIDGE, ENGLAND.

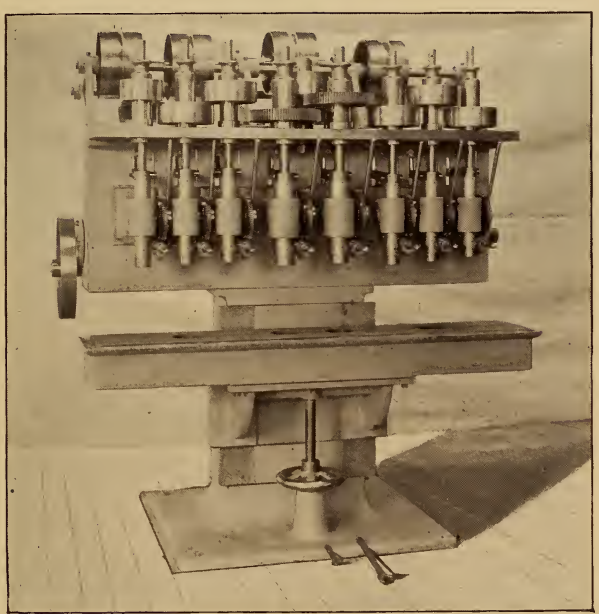
head carrying the drills, and worked by levers, as shown.

On the same cross slide is arranged a tool box or turning rest for turning the edge of the flanged flue or the top. There is also a turning rest at the bottom, so that the top and bottom can be turned at the same time. The chuck which grips the flues is 5 ft. in diameter, with five jaws, all connected with steel bevel wheels, so that the flue ring always remains concentric. The largest diameter that the jaws will grip is 4 ft. 9 in.; the smallest, 2 ft. On the under side of this chuck is a wormwheel for driving the chuck for turning, and for dividing or pitching out the holes from 20 to 140 by a dividing arrangement. The dividing handle, the handle for moving the chuck longitudinally and the handle for the turning rest are close together, so that the workman has not to move. The slide which carries the chuck is arranged to move through the uprights by a screw having a range of 6 ft., 3 ft. on each side of the drills. The driving mechanism is all at the back on the right-hand side of the machine, out of the way of working. The weight of the machine is 17 tons.

A drill for considerably lighter work is the multiple spindle tool built by the Hendey Machine Co., of Torrington,

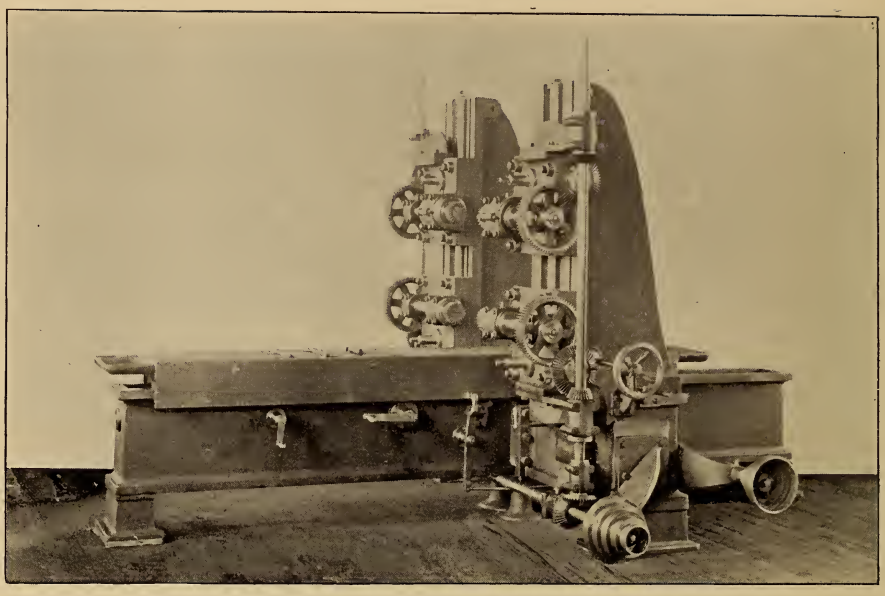
Conn., and shown on this page. This machine was designed specially to drill bicycle tube connections and other parts of bicycle work. As here shown, it is arranged with eight spindles, to drill various sizes of holes, and three speeds. The two center spindles are much larger than the other six, and are for drilling holes up to and including 1¼ in. The other six spindles, three on either side, drill up to and including ¾ in. The heads, spindles and details are so arranged that the machine can be built with any number of spindles, of either the small or large size, or they can be all alike for drilling to ¾ in. or 1¼ in. Each spindle feed can be thrown in or out, independent of the others. Each spindle has a balance weight to lift the spindle from the work as soon as the piece is drilled. Each spindle also has an automatic trip, to throw out the feed when the piece is drilled to the proper depth, and is provided further with a stop to adjust it to proper height when leaving the work. By this means the drill can be stopped very close to the work, so that, in starting it again, no time is lost. The spindles are driven by removable clutches, so that any one spindle may be stopped, and not interfere with the others, as in grinding the drills, changing work, etc.

In the line of milling machines, progress during the last few years has been especially marked, and there has been a growing appreciation of the possi-



MULTIPLE SPINDLE DRILL, BUILT BY THE HENDEY MACHINE CO., TORRINGTON, CONN., U. S. A.

bilities of tools of this class. One of the most recent special designs is that turned out last year by the Pratt & Whitney Co., of Hartford, Conn., for the J. L. Mott Iron Works, of New York. The hot water heaters made by the latter company are composed of hollow rectangular sections, joined at their corners, one to another, and through each corner of which the contained water circulates. The machine was designed to mill, at one operation, the four corners on the top and bottom of one of these sections. It consists of a bed, platen and standards similar in some respects to those of a planing ma-



FOUR-SPINDLE MILLING MACHINE, BUILT BY THE PRATT & WHITNEY CO.. HARTFORD, CONN., U. S. A.

chine. The platen is provided with gearing, by means of which it is moved to and fro between the standards. Mounted on the platen in such a way that they can be placed at any desired distance from each other, are two chucks, between which a section is held. Each standard is mounted in guides at right angles to the bed, so that they can be placed at the proper distance apart to suit the width of the section to be milled.

Each standard is provided with two horizontal spindles carrying the milling cutters. The lower spindle is stationary, but the upper one is adjustable longitudinally for a short distance in order to bring its cutter in the same vertical plane with the one below it. The machine will mill parallel surfaces on work 24 inches wide, or between the pairs of cutters, and will admit work 40½ inches square. Extending across the machine, at the foot of the standards, is the driven shaft. Bevel gears on this impart motion to a vertical shaft on each standard. From these the spindles are driven by gearing.

Another milling machine, but of more generally available design, is that built by Messrs. Shepherd, Hill & Co., of Leeds, England, and shown on the page opposite. It is intended for milling the two sides of a box casting at the same time. It has a bed 14 ft. long, 27 in. wide, and 20 in. deep, carrying a table 8 ft. long and 2 ft. 9 in. wide. The table is moved forward by means of a steel screw taking its motion from a three-speed traverse cone, worm and worm-wheel. The feed is arranged for a milling cutter with 60 tools in it. To the main bed another bed, about 5 ft. long, is bolted at each side, at right angles to it. These beds are 28 in. wide and 18 in. deep and each carries a strong headstock, movable along them, to or from the main bed, by means of a screw, with a worm-wheel and worm for specially precise adjustment.

The headstocks are 3 ft. 9 in. long by 3 ft. wide, and 24 in. centres. They are fitted with cast-iron spindles, 8 in. in diameter, running in cast-iron bushes fitted into square holes, with a strong thrust arrangement, and two hard, grooved, gun-metal washers for taking up the wear and for lubrication. The spindles are each driven by a steel worm, running in oil, and a worm-

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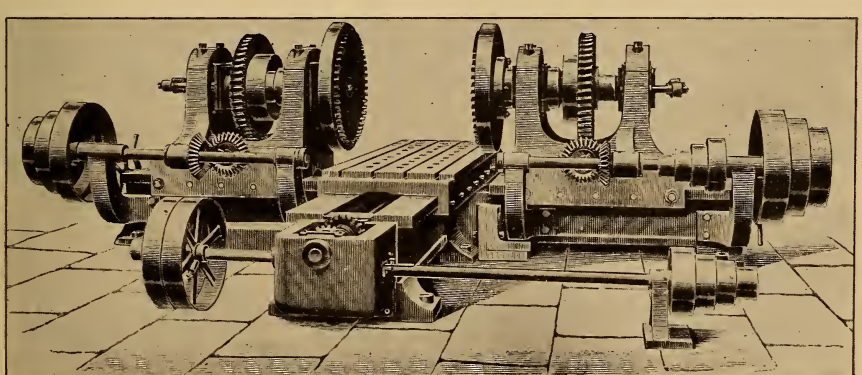
wheel, from a three-speed cone, 5 in. wide. The largest cone is 27 in. in diameter. The table which carries the work is moved back quickly by means of a pair of pulleys and bevel wheels which drive the screw at the opposite end of the bed to the feed gear, the worm-wheel being disconnected. The machine has a traversing cone with four speeds, giving a variable feed to the table from ⅜ in. to 1¾ in. for each revolution of the cutters. It will mill a surface 6 ft. 3 in. long by 2 ft. 6 in. deep.

As a fitting conclusion to this article, reference may be made to at least one of a number of planing machines, the one selected for illustration being the open-side machine built by the Detrick & Harvey Machine Co., of Baltimore, Md. The name "open-side" indicates an important feature embodied in this type of planer, in that it has but one post, this enabling it to be applied to a great variety of work. It is in no sense a "special" tool, as it does the regular line of work of the two-post planer, and, at the same time, will take in castings that could not be planed on that form of machine. In order to obtain this open side for large work, the cross beam is supported entirely from one post. The beam is a right-angle casting with a long, scraped bearing on the post, equal to 1½ times the overhang of the beam. This insures the beam against any vertical spring, and gives the side head a separate bearing on this casting, so that the wear, due to the movement of the beam on the post, does not affect the efficiency of the side head. To overcome the horizontal strain, the beam is supported across its entire width by a brace, which takes a bearing on the back of the post, to which it is rigidly bolted when the planer is in operation. This beam is made very heavy, so as to prevent vibration at the end, even on very heavy cuts.

The driving motion used is that known as the "Sellers spiral planer motion," which, for power, simplicity, durability and smooth running qualities is so familiar to engineers in the United States. As will be seen, the axis of the pulley shaft is parallel to the table. Motion is imparted to the shaft from the countershaft above, and then to the angle shaft through a pair of cut bevel gears. This shaft crosses the bed diagonally, the thrust from the motion of the table being received against a step bearing, the friction being lessened by steel and bronze discs running on one another. The lesser thrust during the quick return motion, which is usually made four to one, is taken up by collars on the other side of the spiral pinion.

On this shaft a spiral pinion is keyed, which gears into a rack, bolted to the table, six teeth being in contact at all times, giving a very smooth and uniform



DOUBLE MILLING MACHINE, BUILT BY MESSRS. SHEPHERD, HILL & CO., LEEDS, ENGLAND.

OPEN SIDE PLANER, BUILT BY THE DETRICK & HARVEY MACHINE CO., BATLIMORE, MD., U. S. A.

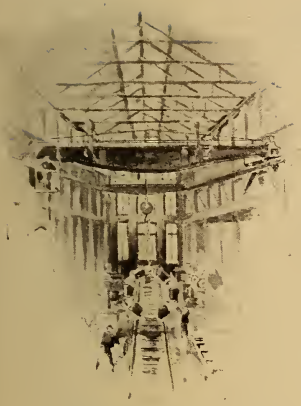
motion to the table. This pinion is, in fact, a short piece of a coarse screw. Being placed on the diagonal shaft, its action differs from that of the ordinary spurwheel, as it also does from that of a worm,—that is to say, if the driving shaft were at right angles to the rack, the pinion would be the ordinary spur ; but if it were inclined to it, say 5 deg., the teeth of the pinion would be required to be slightly curved, and would commence to drive at one side of the rack, shifting gradually to the other as it revolved. The same process takes place at any other angle, the sliding cross motion being more rapid the greater the angle from the perpendicular, until it reaches 90 deg., when it becomes a worm, and the teeth of the rack would then require to correspond with the angle of the thread. With the present arrangement, however, the teeth of the rack must be straight, but may be placed at any convenient angle to the line of the rack. Although the teeth of the latter are straight, and those of the pinion curved, the surface of contact and wear upon the rack is not limited to a small central portion of the teeth, but is uniformally distributed over the whole width of the rack. In this particular case the teeth of the rack are placed at an angle of 5 deg. to its line of motion, to counterbalance any tendency that the pinion may have to move the table sideways.

The driving shaft revolves in long bearings at both ends of the spiral pinion. These bearings are cast in the bed, lined with bronze, and connected by a trough surrounding the pinion. The oil placed upon them can escape only into this trough, and furnishes lubricating material for the pinion or rack. The post, as before stated, takes a bearing on the bed equal to one and a halt times the amount of the overhang of the beam, and being heavily proportioned, is amply strong to resist the strain. The beam is raised and lowered by power transmitted by a friction clutch and then by a worm and wheel to a triple-thread screw, acting on a bronze nut.

The machine will do all the work of an ordinary two-post planer and, in addition, a great variety that would necessitate a much larger tool of the ordinary type. When engaged on a casting with a large overhanging piece, the weight of the outside part is taken on a supplementary rolling table.

MACHINE SHOP ECONOMY.

By Oberlin Smith.



IN these times of fierce competition the subject of small economies, and of improved methods, even in common things, is of the greatest importance—indeed of absolutely vital importance to many machine shops. I speak here of shops, as distinguished from factories. In the former, machinery is made piecemeal, so to speak, or, at any rate, in small quantities of one kind of product at one time. In factories, on the contrary, but few kinds of products are usually made, but these are made in large batches, with every detail brought down to a rigid system. This is attended with a resulting lowering of costs which, in some cases, seems almost marvellous, and with the result also, on account of low costs, of immensely stimulating and increasing consumption.

Taking a general view therefore of the smaller machine shops throughout the country, employing, say, from 10 to 100 men, and varying from the "jobbing" shop, pure and simple, to the semi-manufactory, a close observer will find many ways in which small savings may be made. On the principle that "many a mickle makes a muckle," these savings will, in many cases, amount, in the aggregate, to the difference between failure and success.

In what is known as a jobbing shop, where the work consists mostly of repairs, together with an occasional new machine of a non-standardized kind, and for which the owner has perhaps furnished some of the pieces partly finished, and, at any rate, has furnished designs, there is perhaps less chance for economy than in shops of a higher grade. It is often the case that each particular piece of work depends chiefly upon the individual judgment of the workman in whose care it is put, or upon the judgment of the foreman, who must stay by it and personally supervise the exact method of performing it. For such work a higher class of workmen must be employed, whose experience is of an all-around character, and whose judgment is good enough to enable them to undertake almost any job that comes along. Such men are supposed to have sense enough to do their work reasonably fast, using proper feeds, speeds, etc. If they fail in this respect, however, the loss does not usually come upon the shop management, but rather upon the customer who is supposed to pay by the hour for his work.

In the medium grade of machine shops, where little or no jobbing is done, and, on the other hand, but little real manufacturing,—a type which is vastly in the majority,—some of the economies which should be carefully looked after may be stated in the imperative mood, as follows :

Commencing at the commercial end, pay particular attention to such mercantile matters as are essentials in all

OBERLIN SMITH at an early age started a machine shop that afterwards developed into the Ferracute Machine Company of Bridgeton, N. J., U. S. A., of which he is the president. With many years of practical experience at his command, he can write of "Machine Shop Economy" in a specially interesting and instructive manner.

good business houses, such as judicious advertising of various kinds, proper care in avoiding bad debts, cheap and simple methods of bookkeeping, etc. Avoid taking orders for experimental work of all kinds, unless payment for it by the hour is guaranteed by responsible customers. This has been the rock on which many an otherwise prosperous concern has split, having discovered too late that new and beautiful machines for doing wonderful automatic work appear of a very different value before and after making and perfecting.

In contract work, avoid building single machines of any kind as much as possible. Give preference rather to those orders in which several similar machines are wanted in a batch, even if the price seems considerably lower. Where but few things of a kind are prospectively wanted, avoid elaborate and expensive drawings, but beware of the other extreme and be sure that you have drawings which are very definite in their character, that nothing may be left to guess work, and that alterations may not have to be made in wood and metal instead of upon paper. Pencil drawings, to a scale of ¼, ½ or 1-1, preferably upon cross-ruled paper, are usually good enough for transient jobs. The overlaying of numerous contours in dotted lines should be avoided, but a sufficient number of separate views should be made to leave nothing doubtful. Special attention should be paid to testing the varying positions of moving parts, as levers, slides, etc., by actually drawing these members upon tracing paper, or cutting them out of pasteboard and moving them over the drawing into their extreme positions—all in order that interferences may not occur. See that not only the foreman is well in touch with the draughtsman, but also that the workman who, for the first time, is to produce a new piece of a machine, understands, not from the figured sketch only, but from the scale-drawing itself, the shape, the relation with its fellow pieces, and the functions, of the piece in question.

Pay special attention in the draughting-room to the question of tools, carefully deciding whether all the operations on each piece are to be performed by the general tools in use in the shop, or whether it will pay to make or buy special tools, either for all or part of the work. In general, it may be said that where but a dozen or so pieces of a kind are apt to be wanted within a year it will not pay to make jigs or other special tools for the same, unless, indeed, very great accuracy and interchangeability are desired, or unless the shape is so complicated that ordinary tools cannot be economically used. If, however, from 25 to 100 pieces are likely to be wanted in the near future (leaving out of the question such standard forms as shafts, studs, bolts, nuts, washers, etc., which can either be purchased outside or made cheaply in general tools, such as lathes and turret machines), it may pay to make templets, jigs, cradles, etc., for all or a part of the operations involved. If still larger quantities are wanted, say in the thousands, the work becomes manufacturing, in which case a special and expensive equipment may perhaps be commercially profitable.

In any duplicate work such as we have been considering, provide not only the necessary special tools, but be particular to definitely mark and identify them so that they may not be scattered over the shop and lost. Establish definite places for each, marked with the same symbol as the tool itself, in which they are always to be kept, and for the keeping in which the tool-keeper is held strictly responsible. Furthermore, see that written instructions, illustrated, where necessary, with small photographs or sketches, are provided as directions for the using of each tool. This is in order that when the cheapest way of producing pieces is once ascertained and figured out, such knowledge may not be lost by reason of the workman forgetting his former methods, or by a new workman taking his place. This evil, of course, does not occur in manufacturing on a large scale, as each workman always does one thing and cannot well forget it. In small shops, however, it has been proved frequently

that much of the value of special tools has been utterly wasted, merely by their general scattering, and by nobody remembering just how they were used, especially when an interval of several months, or perhaps a year or two, occurs between the different batches of similar work. When batches are of sufficient size to warrant the trouble, train as cheap a workman as possible (preferably an apprentice) into the use of the jigs and other appliances necessary.

In the process of learning how to rapidly use the special tools in question, as well as in the using of them afterwards, make a special point of the heaviest cuts and the fastest speeds and feeds possible. In doing this, you will probably be surprised to find, as the writer has been, how badly adapted most of the ordinary machine tools in the market are for quick work of this kind. You may not be able to throw out the light and weakly-driven lathes, planers, etc., which infest your shop; in the first place, because, if you did, you could not find any in the market as heavy, strong and powerful as they ought to be; and, in the next place, you probably cannot afford to make so radical a change. There will, however, be found many cases in which the product of a tool can be doubled by putting on heavier belts, or by putting one belt over another, and by changing the feed-gearings, etc. In many cases, also, it will be found that the mounting of angle-plates, squaring-plates, cleats, etc., upon the tables of planers, boring-mills and milling machines, for the sake of being able to rapidly set in position jigs, cradles and other special tools, will be the means of saving a vast amount of time.

One of the worst minor evils of average machine shop practice is the time spent in hunting up innumerable odd bolts and clamps, and the painful attempts at setting pieces of work square and true, together with the fastening of them so that they will not afterwards slip to some other position. Oftentimes a well-meaning workman, with the best intentions, will waste hours of time just because he does not know in what respects the work must be accurate, and in what respects it need not be, and also because he does not know what to set it by, and has not sufficient geometrical training to locate within the metal an imaginary axis, or certain hypothetical planes which were in the minds of the draughtsman, as basic conditions of its final form and its relation to its fellow pieces.

Where there are not definite planes of which the location is easily determined by the workman, and which are finished off flat in the planer or miller, as preliminary operations, and from which the laying out of other surfaces, holes, etc., may be afterwards made, there should certainly be definite centre-lines and other marks scribed upon the work, as indicated by the foreman, or by somebody else who knows the conditions involved. These latter remarks apply of course chiefly to odd work, which is not made with special tools.

After carefully watching for the saving of time in laying out work, and in clamping it, the most important point in all machine shop operations appears, viz., the size of chips and their rate of removal. Slow speeds, shallow cuts and narrow feeding are crying evils everywhere. A general rule to avoid the waste involved by them may be stated as follows:

First—Equip every machine with all the driving power that it is capable of standing without breaking it down, or unduly springing it out of shape.

Second—Take as deep and wide a roughing cut as the machine will drive, providing the work is strong enough to stand it without being broken, bent or unduly sprung out of shape, that is, when properly supported by jacks, steady-rests, etc.

Third—Take as few cuts as possible, preferably either two or three, and usually make the finishing cut shallow and wide, as is customary in all good modern planing, providing undue chattering or springing of the work can be avoided by properly supporting it with clamps, etc., and by having the cutting tool of a shape not to "dig in."

Fourth—Run at as high a speed as is actually possible by a careful experiment with tools of different materials and hardness without unduly wearing away the tool during any one cut, or without costing too much for regrinding of tools. In many cases this high speed process can be vastly improved by the use of oil, soda-water or water—even if some special equipment in the way of tanks, pumps, catch-pans, etc., has to be provided.

Do not allow a workman to think that 16 feet cutting-speed per minute on soft cast-iron is "good enough" because he did it yesterday or last year, or because his grandfather did it. Show him by a definite object-lesson that there is no trouble in doing a good deal of lathe, planer and drilling work at from 25 to 35 feet per minute, even when dry. Milling work may often be done very much faster than this, in some cases approaching 100 feet per minute, on account of many of the cutting edges being out of action, and having time to cool. In certain special cases, where an abundant amount of lubrication can be forced constantly past the cutting edge of the tools, as in drilling deep holes in gun barrels, etc., speeds as high as 3000 feet and over have been attained, and 1800 feet per minute is a very common speed. All this goes to show, what every workman ought to know and have drummed into him every day of his life, that there is no hidden mystery about a tool "standing." Let him understand, once for all, that a steel tool will cut chips off pieces of softer metal at any rate of speed desirable, providing it can be kept cool. By all means get out of his head the ridiculous fallacy that increased cutting speed (leaving out the matter of centrifugal force in rotary work) endangers the tool or the work in the matter of breakage. Teach him, on the other hand, that with a given amount of metal removed per minute, there is vastly less stress upon tool and work at a high speed than at a low one, simply because the chips are smaller. There is, of course, no more stress with a given size of cut, but there is a higher rate of chip removal at the greater speed. Again, I say, emphasize the fact that it is all a matter of temperature, and if the tool can be kept cool, mere velocity of cutting does not count against it.

To impress the above facts upon everybody concerned, a legibly printed and varnished table of speeds, feeds, etc., fastened upon each machine is an excellent reminder. Each speed of a given machine should be known by a letter or number, so that it may be readily referred to upon this table in connection with certain diameters of work appropriate thereto. My own method is to call the fastest speed without gearing, when the belt is upon the smallest pulley of the driven cone, "speed A," the second one "B," the third "C," etc. When the back gearing is thrown in, the letter "G" is appended, making the back geared speeds "AG," "BG," "CG," etc. Should there (as is rarely the case) be double-gearing, another "G" may be added after the first one. By this system, the speed of a machine may be definitely identified, and may be referred to on the drawings of pieces which are to be made in duplicate at a future time Thus we avoid wasting the experience attained in making the first batch, in not allowing the workman to retrograde in his methods, as is so often the case if he is let alone,—and this, too, without his intending to go wrong.

Recurring again to the matter of machine-tool feeds, as sold to us in open market, it may be said that most of them are, on an average, vastly too slow, and also that they are usually very inconvenient to change quickly from one rate to another. Many drill-presses and boring-mills are equipped with proper feeds for drilling into solid metal only, which, of course, are ridiculously slow when used for boring cored holes, where, oftentimes, in finishing cuts, a feed of eight revolutions per inch, and in some cases as high as four, can be used to advantage.

It is not an uncommon thing to see a man using a feed of from thirty to forty revolutions per inch length of hole,

often occupying from one to two hours, upon a hole about 5″ x 7″, in cast iron, which a car-wheel manufacturer would complete (both roughing and finishing cuts) in six minutes. This is not poetry but actual fact—as can be ascertained by any machine-shop owner with careful observation. In the works under my control a number of boring operations which were recently made the subjects of a few special tools, but more particularly of common-sense feeding, have been brought down from about five hours to one-half hour each, by the methods suggested above. In another case, where fifty pieces were wanted in a batch, a couple of rough jigs and improved feeds and speeds reduced the time from nine hours to half an hour.

The worst case of slow feed-gearing that I have seen recently is upon a 36-inch drill-press of first-class make, where the feeds range from 72 to 640 revolutions per inch. Such a machine it would pay to melt in a cupola, rather than not alter,—that is, for boring work.

Regarding the numerous minor economies which can be practiced in a shop, there is not room to treat of here. They ought to be obvious to any capable manager, and consist largely of carefully watching, not only on what kind of work men are employed, how they spend their time, how accurately their actual working time is kept, and other matters relating to the *personnel* of the establishment; but also to the treatment of the *matériel*. This latter consists in economy of fuel and oil consumption, proper shop temperature and illumination, with abundance of light everywhere, cleanliness and general good order, and, above all, "a place for everything and everything in its place."

THE MAXIMUM POSSIBLE EFFICIENCY OF GALVANIC BATTERIES.

By Henry Morton, Ph.D.

SOME recent publications and other intimations indicate that, with the general revival of business, there are likely to be brought before the public various schemes, such as some of those discussed in the writer's recent articles on "Engineering Fallacies," in this magazine, in which electric energy, derived from galvanic batteries, will be relied upon as the source of power. In view of this, it would seem as if a few words on the above subject might be timely, and the writer has therefore ventured to put into shape the appended calculations.

To discuss this question in an exact and numerical manner, it will be necessary to indicate with precision what class of batteries are referred to, and the writer would, therefore, say at the outset that he refers only to those which long experience has proved to be the most efficient in supplying large currents, excluding those of the Leclanché type which yield only feeble currents.

In all the batteries here referred to, there are the following common features:—1st: The energy is derived from the combination of zinc with dilute sulphuric acid. 2d: The supply of oxygen re-

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quired for this combination is obtained by the decomposition of water or some other compound in aqueous solution. In other words, the batteries here considered are the Smee, the Daniell, the Grove and the various forms in which chromic acid is the oxygen-supplying substance.

This being premised we can begin with the following general statement of principles :—First. The source of energy being the reaction between the metallic zinc and the dilute acid, its amount can be expressed in British thermal units as follows :— Oxidation of zinc, 2340 B. T. U.; solution of oxide in dilute sulphuric acid, 666 B. T. U.; or, in all, 3006 B. T. U. as the total energy developed by the union of the zinc and acid. No arrangement of parts or employment of one material or another in other parts of the cell or for other parts of the reaction can add anything to this, but on the other hand there must always be more or less subtracted from it to meet the demands of the reaction, to say nothing of internal resistance of the solutions, local action, etc.

Second. In order that the zinc should combine with the acid, the hydrogen, whose place it takes, must be driven out or otherwise taken care of, and this will demand an expenditure of energy, greater or less, but always considerable. For example, in the Smee battery the hydrogen is simply driven out in bubbles of gas. To do this requires 2106 B. T. U. for each pound of zinc dissolved. Taking this from 3006, leaves only 900 B. T. U. as even possibly available from each pound of zinc consumed in a Smee battery, not counting losses coming from local action, resistance, etc.

This difficulty was realized at an early period and was met by supplying oxygen to take up the hydrogen, and so avoid the great loss involved in expelling it. To supply this oxygen, various substances have been used, but the only ones of practical importance are sulphate of copper, nitric acid and chromic acid. But even with these, more or less energy must be expended in decomposing them and securing their oxygen. The energies involved are : –

	B. T. U.
Sulphate of copper, Daniell battery.	1,587
Nitric acid, Grove or Bunsen battery	283.6
Chromic acid, Poggendorff battery..	178.5

If these various amounts are subtracted from the maximum thermal value of the zinc-in-sulphuric-acid combination, we will have for the several batteries :—

	B. T. U.
Smee battery, as before.....	900
Daniell battery.....	1,419
Grove or Bunsen battery.....	2,722.4
Poggendorff (chromic acid).....	2,827.5

These figures represent the absolute maxima of energy which a pound of zinc could develop in these forms of battery, excluding all losses from resistance, etc. To get a practical view of these results, however, it will be necessary to reduce them to equivalent foot-pounds of work and to horse-power rates of doing work.

Joule has shown that each British thermal unit is equal to 772 foot-pounds, and this means that the energy expressed by the heat which will raise one pound of water one degree Fahrenheit (this is the British thermal unit) would lift one pound 772 feet, or 772 pounds one foot. If, then, we multiply the figures given above, we shall have the various energies, expressed in foot-pounds of work. In other words, a pound of zinc, consumed in these various batteries, would develop the following numbers of foot-pounds, all losses from resistance, etc., being excluded :—

	Foot-pounds.
Smee battery.....	694,800
Daniell battery.....	1,095,468
Grove battery.....	2,101,694
Poggendorff battery.....	2,182,820

If, in each of these batteries, one pound of zinc were consumed in a minute, then the above numbers of foot-pounds would represent the work developed in a minute in each case, and to turn this into horse-power we should divide each number by 33,000, because a horse-power is a rate of doing work of 33,000 foot-pounds each minute. This will give us the horse-power rep-

resented by the solution of one pound of zinc each minute in each battery.

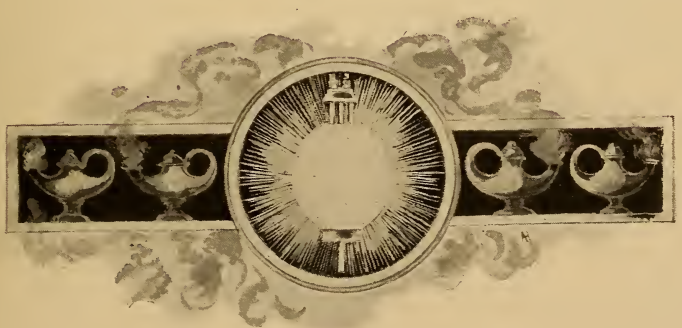
Smee battery....	21.05	H. P.	for	one	minute
Daniell battery...	33.19	"	"	"	"
Grove battery....	63.66	"	"	"	"
Poggendorff bat'y	68.57	"	"	"	"

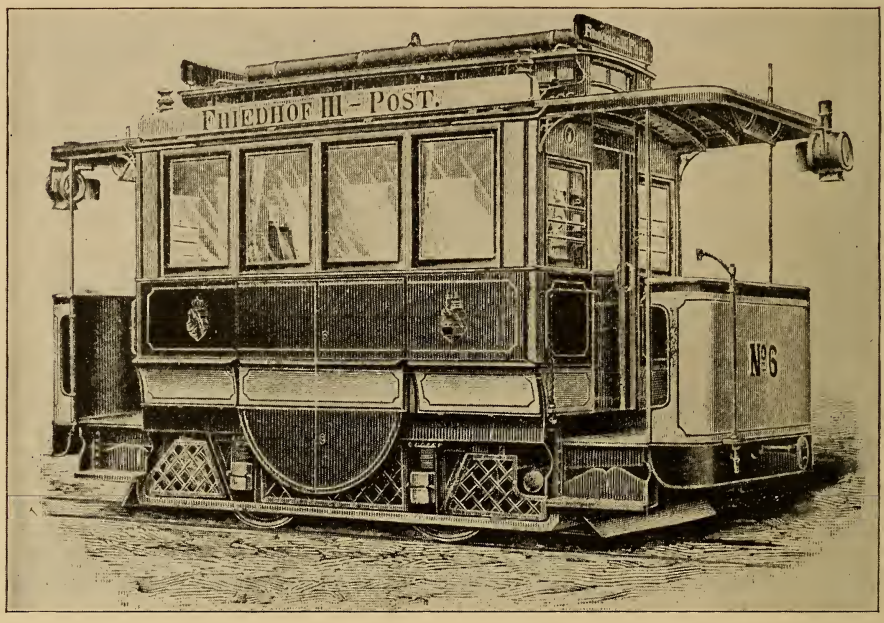
Such a rate of consuming zinc as a pound a minute would, of course, require an immense galvanic battery, and indeed it is usual to express the consumption of fuels generally in pounds per hour. To get the horse-power due to the consumption of zinc at the rate of a pound an hour, we divide the above figures by 60, and this gives the horse-power developed by a pound of zinc consumed during an hour as follows :—

Smee battery.....	0.35,	or about	⅓	H. P.
Daniell battery.....	0.55,	"	½	"
Grove battery.....	1.06,	"	1	"
Poggendorff battery	1.14,	"	1⅛	"

This shows that in the best forms of battery an allowance of one horse-power for each pound of zinc consumed per hour would be a liberal one, if something is allowed, as it must be, for the resistance, local action, etc. It may, however, be asked,—If such an improvement has been made as above shown from the Smee battery giving ⅓ to the Poggendorff yielding 1⅛ horse-power, may we not expect further improvements as great in amount? To this I answer certainly not in this class of batteries. The entire energy of the reaction between the zinc and dilute acid is 3006 British thermal units. This would represent 2,320,632 foot-pounds or 70.62 horse-power for one minute, or 1.17, say 1⅙, horse-power for one hour, and this would be an absolute maximum which could never be reached, far less exceeded.

Of course, if we could use some other, and more efficient, reaction than that between zinc and sulphuric acid, some gain might be secured, but nothing of that sort has ever been accomplished, nor from what is known of the combining or thermal equivalents of the available elements, is much to be expected in that line. At all events, we may well accept this as a certain fact, that in any known form of galvanic battery the round figure of a pound of zinc per horse-power per hour is an outside figure for efficiency, and when anyone asserts that more than this has been secured, there is certainly some mistake or fraud.





THE LÜHRIG GAS-MOTOR STREET CAR AT DESSAU, GERMANY.

GAS-MOTOR STREET CARS.

By Frank H. Mason.

THE conditions under which tramways are built and operated in most European countries differ somewhat from those which prevail in most cities of the United States. In general, street railways were adopted in the Old World long after they were successfully used in America, and since then, European tramway companies have been much more rigidly controlled in respect to speed, frequency of service, rates of fare and especially the cost of their franchises, than has been the rule under the generous and easy-going authority of most American cities.

FRANK H. MASON was appointed United States Consul at Basle in 1880; was transferred in 1884 to Marseilles, France, and in 1889 was made Consul-General at Frankfort-on-the-Main, in Germany. He is the author of several magazine articles and a long series of consular reports on various industrial, commercial, and scientific topics.

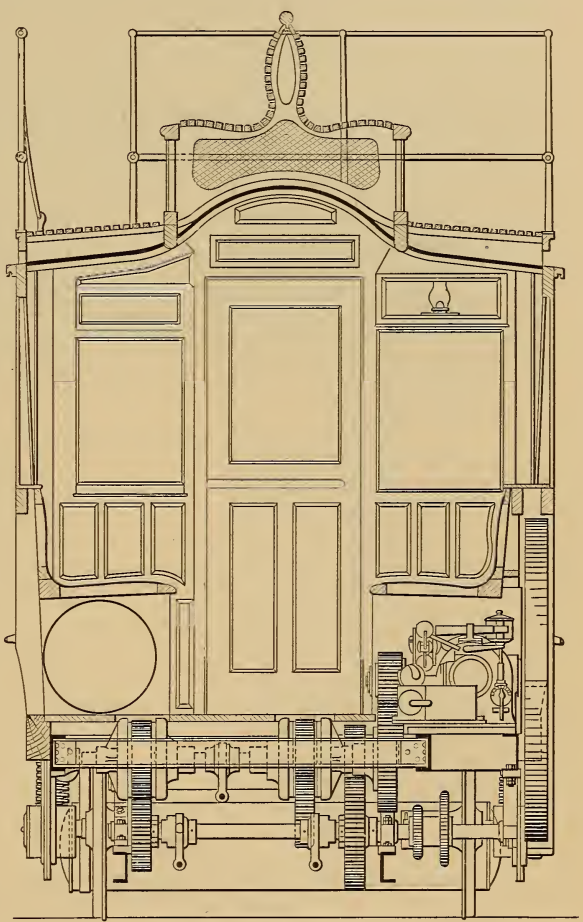
Most European municipalities object to the trolley and to overhead wires generally; traction cables are rarely used, except in cases of heavy grades on suburban lines, and busy streets are rarely surrendered to steam tramways. Particularly is all this true in Germany, where sharp restrictions are made in respect to fares, frequency of service and the number of passengers which a car may carry. Crowded platforms and standing in aisles of street cars are generally forbidden. As a result of this and the high cost of horses and forage, the profits of horse railways in

Germany have been, hitherto, rather limited, and the companies have been forced to exercise the utmost economy in equipment and management.

Out of these general conditions has grown the gas-motor street car, which promises important results in respect to economy, and which, during the past two years, has reached a state of development which has challenged the attention of engineers in other countries. The gas-motor car which is now foremost in Germany was invented by an engineer at Dresden, name Lührig, who hit upon the idea of a connection between the motor and running gear of the car by means of friction clutches controlled by the driver, so that the engine can be kept in continuous action while the car is in service, and the latter can be started and stopped by throwing the clutches into and out of engagement. In Lührig's original model the car was equipped with two double-cylinder gas engines of the Otto type, one being placed under the seat on each side of the car. This made the car unduly heavy and costly, and, moreover, exposed it to an uncomfortable vibration at the moment of starting and when rounding an abrupt curve in the line.

In the midst of his experiments Lührig died, and his invention was taken up by a corporation known as the Traction Syndicate, Limited, with offices at London and Dresden, at which latter point cars for use in Germany are now built. Under the management of the syndicate the car was rapidly improved and simplified, the motive power was condensed to a single, double-cylinder engine, and the weight and cost of the whole apparatus were proportionately reduced.

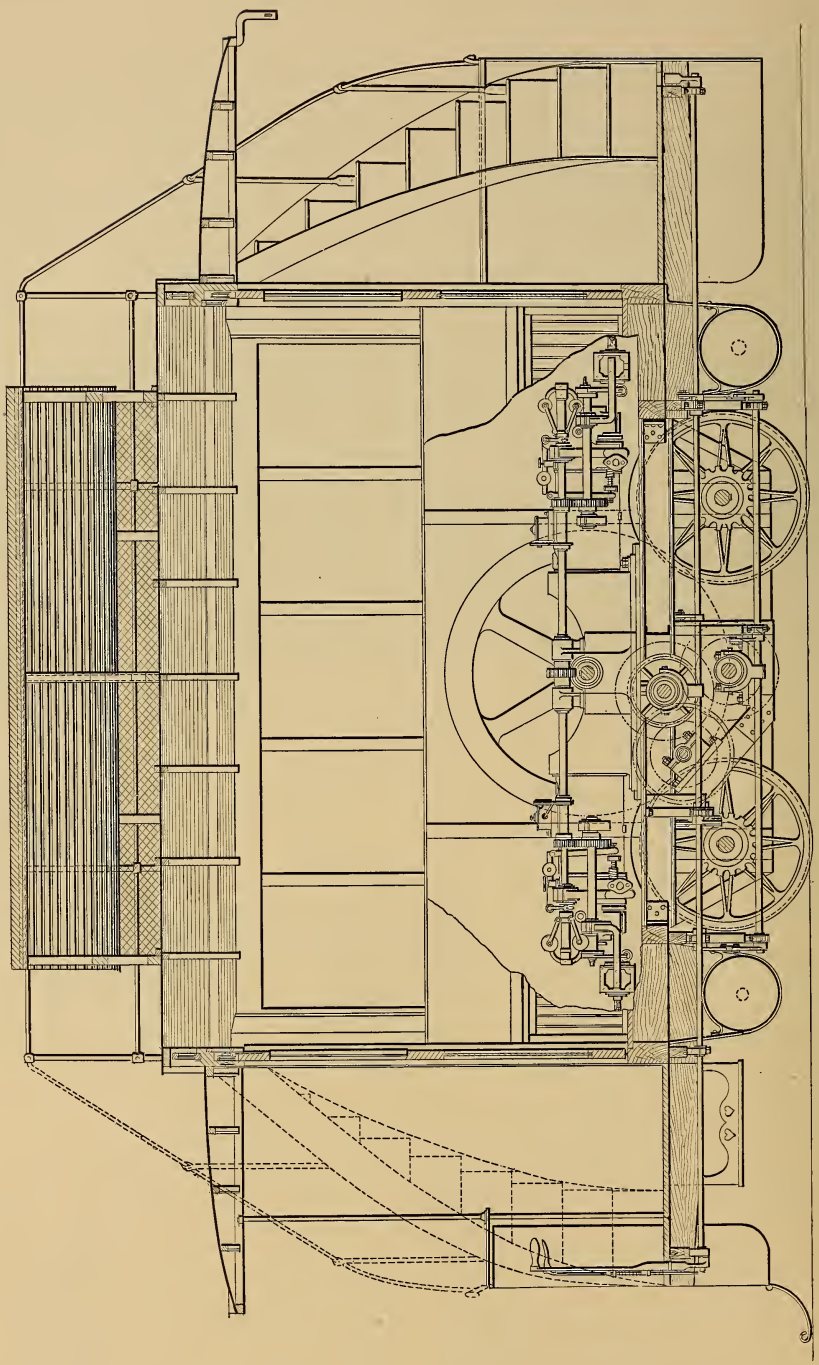
There are now in operation in Germany two lines of Lührig cars of the latest and most improved pattern; one, about three miles long, at Dessau, which was opened for traffic in November last, and the other, the original line, at Dresden, leading from a central point in that city to a suburban village several miles distant. During the past year successful experiments have been made by the English branch of the syndicate,



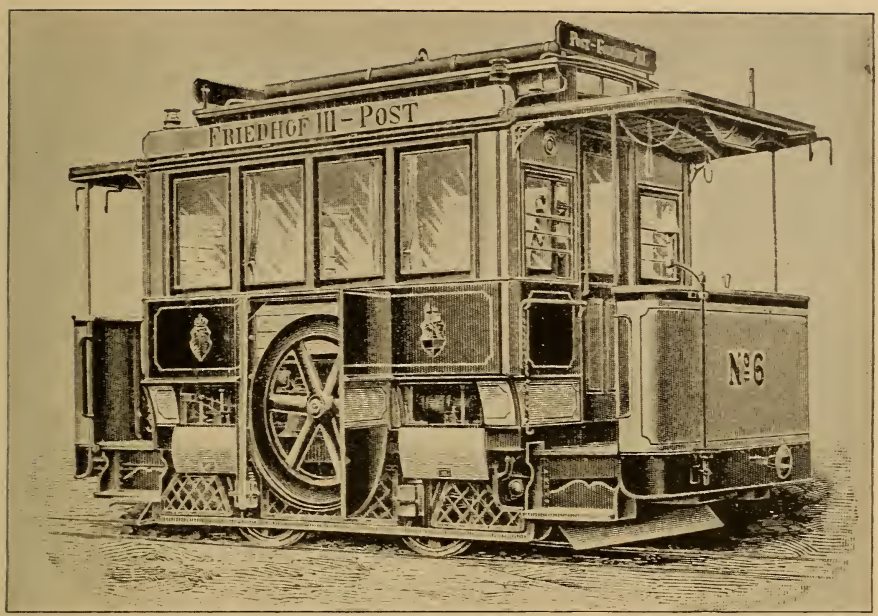
CROSS SECTION OF CAR.

which built and operated an experimental car upon a tramway at Croydon, a few miles south of London. In the accompanying illustrations the outline drawings show the English model, while the others represent the cars in use at Dessau.

The progress of this invention has been described by the writer in successive reports to the United States



SECTIONAL ELEVATION OF A LÜHRIG GAS-MOTOR CAR.



THE CAR WITH SIDE-DOORS OPEN, SHOWING THE MOTOR.

Department of State, from the last of which, published in the United States Consular Reports No. 173, February, 1895, is condensed the following description of the improved cars which were put in operation at Dresden during the summer of 1894, and have since been in daily service from six o'clock in the morning until ten at night, working side by side with horse cars with which the line was originally equipped, so that a close comparison has been secured between the two systems, operating under practically identical traffic conditions.

Outwardly, the car's appearance is precisely similar to that of an ordinary double-decked horse car, having stairways from each platform to the seats on the roof. All the machinery is inclosed and concealed from sight; there is no smell of gas, no noticeable heat from the engine, and no undue noise or jar when the car is stopped or set in motion. The motor, as already remarked, is a double-cylinder gas engine of the Otto model, placed under the seat at one side of the car, and reached, for purposes of oiling, cleaning, or repairs, by doors which form panels in the outer wall of the car. When closed, they are not noticeable. The gas charge is ignited at each stroke by an electric spark from a small battery located in the engine space, so that the car is put into or out of service by turning a knob which opens or closes the battery circuit.

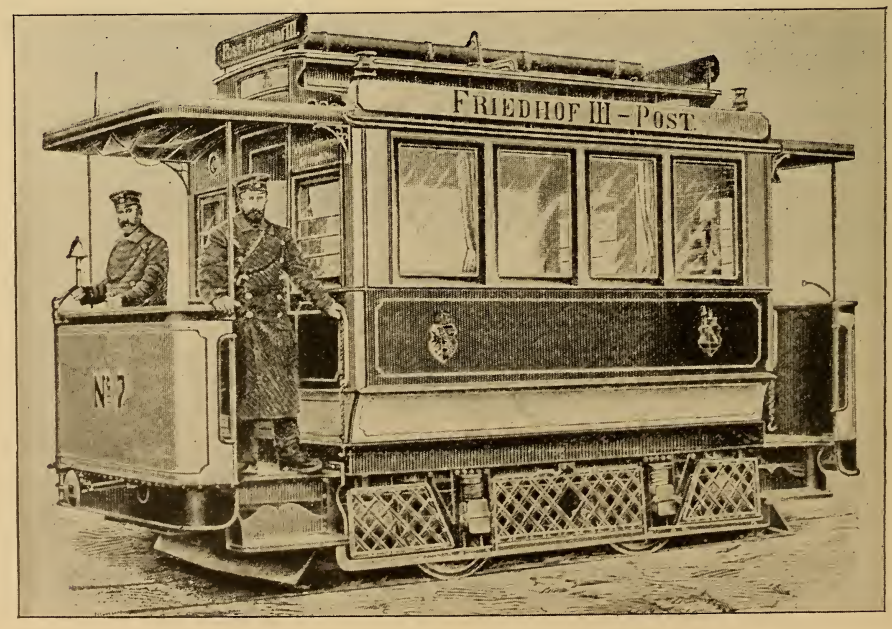
The engine is kept in continuous motion while the car is in service, and the whole is managed by the driver, who, standing on the front platform, has within reach the brake wheel, on which is fixed the alarm bell, and a movable lever which, when in an upright position, leaves the engine disconnected with the running gear of the car and cuts off the gas supply, so that but one explosion takes place in one of the cylinders at each eighth revolution, the motion of the engine being meanwhile maintained and steadied by the fly wheel, which is 4 feet in diameter and of corresponding weight. When the lever is pushed to the left, it turns on a two-thirds supply of gas in both cylinders and brings into action a friction clutch which connects the engine shaft with the wheel axles and gives the car

a speed of 4½ miles an hour. Pushing this lever to the right, turns on the full gas supply and brings into action a friction clutch of larger diameter, which gives the car a speed of 9 miles an hour. A second lever is provided for reversing the engine.

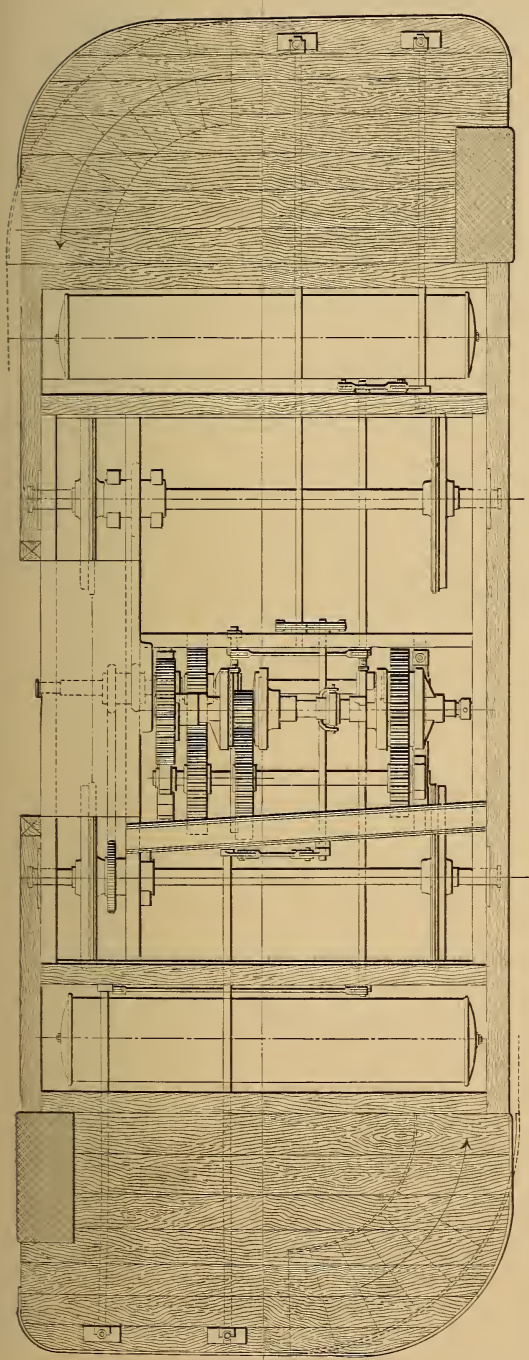
The gas supply is carried in three cylindrical reservoirs of boiler iron, about 10 inches in diameter, two of which are hung transversely under the floor at each end of the car, while the third is placed beneath the seat at the side opposite the engine. The weight is thus, to some degree, equalized. The three reservoirs weigh, together, about 550 pounds, and contain 33.5 cubic feet of gas, compressed to a pressure of 8 atmospheres by means of an ordinary force pump at the end supply station. This pump is worked by a gas engine of 8 horse-power.

A fourth cylindrical reservoir, containing water for cooling the engine cylinders, is placed beneath the double seat along the middle of the deck roof, whence the cool water descends and the warm ascends automatically through concealed copper tubes, so effectively that the water, being continually cooled in the exposed reservoir, is used over and over again, and keeps the cylinders down to the requisite temperature. The gas reservoirs are charged at the end station by means of a flexible hose, leading from the compressor plant, and the charging process occupies from 30 seconds to a minute, according to the calibre of the hose and the degree to which the gas in the reservoirs has been previously exhausted.

The ordinary car is equipped with a gas engine of 9 horse-power and carries 36 passengers, viz.: 14 seated inside, and 12 on deck, with platform standing room for 10 more. The car costs, in Germany, 12,000 marks. When it is desirable to make the motor car capable of drawing a trailer during hours or days of increased travel, the engine is increased to 12 horse-power, and the car then costs slightly more. The work of the motor cars seems to have fulfilled substantially all that has been claimed in their favour. The car is perfectly manageable, stops from full speed within its own length, starts without noise or shock, is free from



THE OTHER SIDE OF THE CAR.



A FLOOR PLAN.

heat or smell, runs as smoothly as a horse car on what would be considered in England and America a rather rough and poorly constructed track, far surpasses a horse car in speed when the way is clear, and is handled safely and easily on a boulevard which, at certain hours, is crowded with traffic that renders frequent and sudden stops necessary. At the slower rate of speed it mounts a grade of 1 in 22, and traverses, uphill, a curve of 40 foot radius.

Exact and conclusive comparisons of net cost and operating expenses, as compared with other systems of propulsion, can, of course, be deduced only from prolonged and continuous service covering a period of years, but from the experience thus far gained, some of the essential factors in the problem may be closely approximated. Gas is furnished by the street gas company in Dresden at its usual rate, of about 4/2½ per 1,000 cubic feet. At this price, the cost for gas consumed by a car in service is a half-penny per car-kilometre. The initial cost of a gas motor car does not differ much from that of a new horse car with its complement of horses. The gas reservoir station for a large line occupies but small space, and can be managed by one or two men, and the cars, when not in service, consume nothing and require only a shed for shelter from the weather. One cleaning per week is found to be sufficient for the machinery, which is tightly inclosed and protected from dust and dampness.

In Germany, good horses for tramway service cost from £40 to £50 each, and their average efficiency does not exceed three years, at the end of which time they are either worn out, or, if salable for breeding purposes or farm work, they bring only from one-fourth to one-half of their original cost. In Dresden, the annual depreciation of street-railway horses from all causes—disease, accident and inevitable wear from hard service in all weathers on hard pavements—is reckoned at from 18 to 22 per cent. of their value, and this percentage is said to be still higher

in tropical or very cold countries, where only inferior breeds of draft horses are available and the conditions of animal life are less favourable.

The cost of keeping a gas motor car in repair, although not yet fully demonstrated for a long period, is estimated at not more than 5 per cent. annually of its original cost, and with ordinary care such a car should last as long as two or three outfits of horses, which latter are, moreover, subject to epidemics and to conscription, in case of sudden war, for military service. So far, therefore, as experience has yet demonstrated, the mechanical efficiency of the gas-motor car would seem to be assured ; and a comparison of its cost of construction and operation with the known expense of working horse, cable, steam and electrical tramways in the United Stater can hardly fail to invest the new motor, as a competitor in the same field, with a serious practical interest. Further improvements will, no doubt, still better adapt it to its work under varying local conditions, but in its present form, it would not seem to be well suited to lines which have grades more abrupt than 1 in 20, and it has not yet been proven to be well adapted to countries which are subject to frequent and heavy falls of snow.

PHILIP HICHBORN,

Chief Constructor, United States Navy.

By Robert Gregg Skerrett.

FROM an humble apprentice to the responsible dignity of Chief Constructor of a powerful navy is a stride to be appreciated only when one realizes the constructive magnitude of mighty fighting ships and learns, too, how much the policy of that officer may affect the development of the right arm of a nation's defence. Such, in brief, is the life of Philip Hichborn, born at Charlestown, Mass., March 4, 1839. The descendant of an old colonial family of unquestioned patriotism,—Deborah Hichborn being the mother of Paul Revere,—and of a stock that later became one of the foremost of those renowned ship-building and seafaring families of New England, Mr. Hichborn's life-work has been the direct result of inherited qualifications, put to their best use.

Robert Gregg Skerrett is a son of Admiral J. S. Skerrett U. S. N, retired. For the past seven years he has been identified with the Bureau of Construction and Repair of the United States Navy Department, and has written about and illustrated most of the new ships of the American Navy.

Graduated from the Boston High School at sixteen, he was indentured, shortly after, to the United States Government as a shipwright apprentice at the Charlestown Navy Yard, and, in addition to his five years' successful apprenticeship, worked at night school with commendable results throughout the term of his minority. While under governmental instruction, and in recognition of merit, Isaac Toucey, then Secretary of the Navy, ordered that young Hichborn should receive a course of theoretical training. The consequence of those two years of close application was an unusually youthful proficiency in ship construction, calculation and design.

Persuaded by his preceptor, Melvin

Simmons, who had entered the service as a naval constructor and had been detailed to California for duty, Mr. Hichborn, at twenty-one, signed as carpenter of the clipper-ship Dashing Wave, and sailed from Boston for San Francisco in August, 1860. His purpose was a broader and higher mission in life to which that office was but a step, and the hundred and fifty days of that trying and tempestuous trip were fruitful of lasting impressions. From an easy-going willingness, with fair weather and reasonable food, he saw the temper of that limited crew sharpen under pinched fare, bitter weather and divided authority, till open violence seemed inevitable; and, again, saw the mood change to impudent indifference as the climate moderated and their destination neared. He witnessed the stages from neglected sickness and accidental death to something just this side of mutiny and murder, and learned the lessons of considerate management and self-control.

Reaching San Francisco, he worked for some time with the Pacific Mail Company, but soon left to enter governmental employment under Mr. Simmons at the navy yard at Mare Island, and from a journeyman shipwright rose, in two years,—at the age of twenty-three,—to the responsible position of master shipwright of the station,—an office often involving the direction of a thousand men, and, in one instance, the complete control of the construction department during the constructor's absence, during which time he hauled out and rebuilt the old paddle-wheel Saginaw.

In 1864 he was tendered an appointment as assistant naval constructor, but declined because the salary allowed was less than he received as master shipwright. In 1869, however, he made application for the position he had previously refused, and after a severe examination was duly appointed an assistant naval constructor in June of the same year. Six years later he became a full constructor, having distanced all his competitors in a very rigorous examination, whereby he maintained his file on the register and gained his commission marked number one.

Mr. Hichborn's California life was an eventful one, and his remembrance of those days is full of rich and vivid reminiscences of those times when might out there often meant right, and when it was not wise to inquire too closely into your neighbors' affairs. While West, and during the War of the Rebellion, he was made vice-president of the Union League of Vallejo, the small town neighboring Mare Island. Both he and the president of the association were informed that they were to be made away with were they to try to vote at the coming election. In spite of the entreaties of friends, Mr. Hichborn determined to vote at all odds, for as he said, he had to live among those people, and example meant everything. When the day came, with his ballot in one hand and the other armed and housed in his coat pocket, he walked forward, with as much composure and smiling recognition as possible, up to the box between two rows of uncongenial-looking citizens, knowing all of them to be loaded with something a deal more searching than the spirit of the time only. A moment's hesitation or fear, or an unwise word or the least cause for disapproval would have hurried him into oblivion and turned that mixed crowd of friends and foes into a riotous, blood-thirsty mass. Such trials are the making of men, and in his case developed that positiveness of purpose that characterizes him today.

In May, 1870, he was detached from Mare Island and ordered to the navy yard at Portsmouth, N. H. His departure was universally regretted. The day on which he left was declared a holiday in the construction department, and, headed by a brass band, virtually the whole town of Vallejo escorted him to the station in spontaneous evidence of the general esteem in which he was held by his fellow townsmen of ten years' association.

In 1875, while at Portsmouth, the Ticonderoga arrived at the station with

yellow fever aboard, and by the Navy Department's order the vessel was submitted to a thorough cleansing and fumigation. Mr. Hichborn personally superintended the whole work, and when the task was well-nigh finished was stricken with a severe attack of typhoid fever. This example of self-forgetfulness was only one instance among many; he never ordered a man to go where he feared to venture himself, and often, indeed, went unfollowed to make sure of the safety of his subordinates. From his admission to the service up to the present time his life has been one of uninterrupted usefulness and activity in the immediate concerns of the United States Navy, broken once only by his official tour of European dock-yards, of which his published report of two eagerly-sought editions gives but a restricted idea. The work became at once a text-book among the profession.

Upon the advent, in 1881, of the present naval policy of the United States, he was made a member of the first Naval Advisory Board, and was prominently associated with all matters affecting the designing of new vessels as well as the practical and useful remodeling of several old monitors of doubtful utility. In 1894 he was ordered to the Navy Department as assistant chief of the Bureau of Construction and Repair, and continued so until his appointment as Chief Constructor, July, 1893.

The life work of a naval officer is unlike that of a civilian in so far as the result is generally known only by association with the public recognition of the chief in authority, and the mass of Mr. Hichborn's practical energy must be left unknown and unpraised save by his fellow officers and his admiring subordinates. Of his inventive genius, the "Franklin" life-buoy, automatically ignited by the action of water on phosphide of calcium, and the "Hichborn barbette turret," admired, complimented and, in principle, copied abroad, are two instances in which the public have known and heard of him. Full as his life has been, he has still found time to do considerable literary work of a professional nature, and his brochure, "Sheathed or Unsheathed Ships," has opened the eyes of thinking men to the relations of economy and efficiency in fighting ships.

By a recent order of the United States Navy Department regarding the bureau's work, Mr. Hichborn has been raised to a dignity comparable to that of the Chief of Construction of the British navy, and to this added responsibility he responds without the slightest tax upon his seemingly inexhaustive resourcefulness. His present eminence is the reward for a life of unfailing energy, guided by a mind singularly adapted to his calling. Personally, he is in all things the embodiment of manly and mental vigor, softened to a charm by a heart at once generous to friends and fair to those less kindly disposed.

ELECTRICITY FOR MARINE PROPULSION.

By Professor W. F. Durand.

IDEAL conditions in marine propulsion are evidently to be sought in a store of energy of such form that the maximum amount shall be embodied in the minimum weight and volume ; in such a relation between this form and the motor or utilizing apparatus, that the maximum fraction may be rendered actually available for propulsive purposes ; and in a motive apparatus of minimum weight and volume for the power developed.

These considerations are purely of an engineering character. In addition we have, as commercial considerations, the cost of energy delivered on board, and the first cost and cost of maintenance of the necessary machinery and equipment. Besides these there are a number of considerations relating to general adaptation, convenience for special purposes, etc. Any proposed scheme of propulsion must, as a whole, be judged from all of these standpoints in connection with the special circumstances of the case.

In order to compare electricity with steam, let us examine each method briefly under these several heads, using for quantitative comparisons such figures as shall seem fairly representative for the cases under consideration. We first note the weight and volume required for energy embodied in coal. Taking 14,000 heat units as potential in a pound of coal, and 42 cubic feet bunker space per ton of 2240 lbs., we readily find that one cubic foot of bunker space will contain about 53.3 lbs. of coal embodying about 580,000,000 ft. lbs. of potential energy.

For comparative purposes we shall consider the utilization as the amount delivered to the screw shaft. Under the usual conditions of marine propulsion this may be taken at from five to eight per cent. As convenient units of power and work we shall take the horse-power and the horse-power per hour. We thus find that the work unit potential in coal requires about 0.18 lb. mass and occupies about 0.0034 cubic feet of bunker space, while, with six per cent. efficiency, the same unit at the shaft will require 3 pounds of coal and 0.056 cubic feet of bunker space.

Turning now to the weight of motive machinery, we shall find most cases included between limits of 100 and 300 lbs. per indicated horse-power. These limits would be only slightly increased by referring the weight to shaft horse-power rather than indicated, and we may take 200 lbs. as fairly representative for the weight of total machinery per shaft-power unit. As to the volume required for the machinery, it is difficult to give figures which are even approximate. Comparisons under this head between the two methods of propulsion will, however, be made further on.

In addition to coal and machinery, there will be required on board certain stores or supplies directly necessary for the development of the power. These may include fresh water, oil, waste, spare and emergency parts, etc. Water is perhaps the chief item, especially for salt water navigation with small craft, and, in any event, is the chief item of difference between the two methods of propulsion. Its amount we may take

WM. F. DURAND graduated in the engineering course at the U. S. Naval Academy in 1880, and remained in the Naval Service as assistant engineer until 1887. In 1891, when the Graduate School of Naval Agriculture and Marine Engineering at Cornell University was organized, he was offered the position of principal, which he accepted and has held since that time.

at one pound per work unit. Turning next to commercial considerations, we will take coal at $4 per ton of 2240 lbs. It results that one work unit embodied in coal will cost 0.032 cent, while to develop the same amount of work on the shaft the coal will cost 0.53 cent. With regard to the cost of engines and boilers, there is, of course, the widest range of values. In order to take a definite figure, we will assume $40 per shaft power unit, exclusive of the shaft and propeller. The cost of maintenance of engines and boilers, including their repairs, is so dependent on special circumstances that no definite estimate can be made. Comparisons under this head will, however, be noted at a later point.

We come now to the question of similar considerations for the electrical scheme of propulsion, which we may examine under the two heads of (1) batteries and (2) motor. The energy is embodied in the first in a potential form, in a manner somewhat like that in which it exists, due to the relation between carbon and oxygen, in the case of coal. There is this difference, however, that in the latter case the material which serves for the embodiment of the energy is consumed, as we term it, and the products of the process of liberation escape and can be used no more.

With storage batteries, on the contrary, the liberation of the energy does not result in the destruction of the battery or its contents. The operations are, with slight reserve, reversible, and it follows that the battery may be repeatedly used for the storage of energy in a manner somewhat analogous to that involved in the storage of energy by the winding up of a weight, or by the compression of a spring. As implied above, however, certain minor actions of the storage battery are non-reversible, and in this way, as well as in others of a more mechanical nature, an element of wear is manifest. The fact that the battery is not itself consumed as the energy is liberated may seem to suggest its similarity with the boiler or furnace in which the energy of the coal is made manifest, and which, itself, is not consumed. This analogy is, in a measure, correct, but it fails at a point very important for marine purposes. The difference arises from the fact that the boiler or furnace has nothing to do with the original embodiment of the energy, but only with its liberation and transformation. The size of the boiler will depend, therefore, on how much power is needed, but not, except indirectly, on the length of time for which such power is required. On the other hand, the size of battery must necessarily depend on the total amount of energy required, and, therefore, jointly, on the power and the time. It follows that, so far as weight on board is concerned, the battery is analogous to the coal; while in cost of maintenance, the cost of charging is analogous to that of the coal; and in deterioration, the battery and boiler may be considered as analogous. Turning, next, to the motor, we find an exact analogy with the engine.

We have now to consider the weight of storage battery necessary to the embodiment of the work unit. The capacity of batteries is usually stated in ampère-hours, and if the average pressure during discharge is taken at 1.9 volts, it follows that one ampère for one hour is the equivalent of 1.9 watts per hour, or to 1.9÷746 horse-power per hour. We may thus determine the capacity of the battery in terms of the horse-power per hour as unit. Comparing this with the known weight, the desired relationship is determined.

In this way we determine that lead storage cells, as now constructed, usually weigh from 90 to 150 lbs. per work unit embodied. With the very lightest possible type of construction it seems possible to reduce these figures to perhaps 60 or 70 lbs. as a minimum. The greater care necessary in the construction of such cells, however, as well as their shorter life, both point to a higher figure as the lowest permissible for practical work. As a definite figure for comparative purposes we will take 100 lbs. With regard to the volume necessary for the embodiment of the work unit, we find, in a similar way, that with usual modes of construction,

from about 0.6 to 1 cubic foot will be required.

Taking up, next, the question of efficiency, we find naturally some variation with different types of motor, and with varying rates of output and other circumstances. Most cases will fall, however, between 75 and 85 per cent., and we may take 80 per cent. as a fair value. It follows that the development of one work-unit at the shaft will require about 125 lbs. of battery, occupying about one cubic foot of space.

Turning to motors, we find a considerable range of weight per power-unit. As with steam engines, we find also that, in general, large motors are lighter per power-unit than small ones, and high-speed lighter than low-speed ones. For motors of from 5 to 50 horse-power, present construction gives about 75 or 100 lbs. as the minimum weight per power-unit on the armature or screw shaft.

With regard to the relative amounts of space required for the engine and boiler on one hand and the electric motor on the other, we know that in the former case the entire machinery is found to require a considerable portion of the valuable internal volume of the boat, including usually an entire section for a certain length fore and aft. With the electric motor the weight itself is less, and the design is so compact that the volume occupied is almost inappreciable. In fact, it is usually so small that otherwise unavailable space in the stern or bilge will be found ample for its accommodation.

Turning, now, to the commercial features of electrical propulsion, we find that a fair value for the cost of energy stored in batteries is about 3 cents per work-unit of battery output, or about 3.75 cents per work-unit on the shaft. Comparing this with the cost of coal, we find that energy in batteries is about 100 times as expensive as energy in coal. Owing to the superior efficiency of the electric motor, however, this ratio becomes reduced to about seven when we compare equal amounts of work delivered to the shaft.

The causes of this great difference in cost are chiefly two in number: (1) The intervention between the steam engine and screw shaft of a dynamo, battery, motor, wiring, etc., thus causing a loss of energy and necessitating the consumption of about twice as much coal for the production of a work-unit at the shaft with the electrical machinery, as with steam machinery of about equal efficiency but coupled direct. (2) The interest and maintenance charges on this intermediate machinery. It appears, therefore, that while we may consider coal as a natural product, energy embodied in storage batteries must be considered as an artificial product, standing at the end of a series of transformations, in all of which more or less energy is lost, and requiring the operation and maintenance of expensive machinery.

For the first cost of storage batteries we may take $6 per 100 ampère-hours as a representative figure. On this basis the cost per work-unit of battery output would be about $23.50, and per work-unit at the shaft about $30. The cost of motors in such sizes as would be appropriate to the propulsion of launches and small yachts may be taken at $30 to $50 per horse-power on the shaft.

We will now recapitulate the principal points thus far developed. For equal amounts of energy embodied, storage batteries weigh about 550 times as much as coal, and occupy about 220 times as much space. For equal amounts of work on the shaft, the batteries weigh about 40 times as much as coal, and occupy about 16 times as much space. For the same power developed, the weight of electric motors is considerably less than that of ordinary steam machinery, while the space occupied is so small as to be well-nigh inconsiderable when compared with that required for boilers, engines and auxiliaries. For equal amounts of energy embodied, the cost of charging batteries is about 100 times the cost of coal. For equal amounts of work on the shaft, the cost of charging batteries is about 7 times that of coal. For equal amounts of work on the shaft, electric propulsion will require the initial consumption of nearly twice as much coal as with steam pro-

pulsion direct, the two steam engines involved being of about equal efficiency. For equal power on the shaft, electric motors will cost nearly as much as total steam machinery. The initial cost of batteries is an item having no exact parallel in propulsion by steam machinery. The cost depends on both power and time.

The elements of weight may be put into algebraic form as follows :

Let the boat require H shaft-horse-power for a period of t hours.

Let h be the weight of total machinery per shaft power-unit.

e, the weight of material necessary for the embodiment of one shaft work-unit, and

s, the weight, for the same unit, of stores, supplies, etc., as above explained.

We have then,

Total initial weight $= H(h + t(e + s))$.

Total initial weight per power-unit $= h + t(e + s)$.

These are termed initial weights, because, as the coal and stores are used, the weight on board is continually reduced. If at the end of t hours we suppose them exhausted, we shall have, as the mean weight per power-unit,

$$w = h + \tfrac{t}{2}(e + s)$$

For electrical propulsion, only the items represented by s are consumed, so that in this case we have as the mean weight per power-unit,

$$w = h + t(e + \tfrac{s}{2})$$

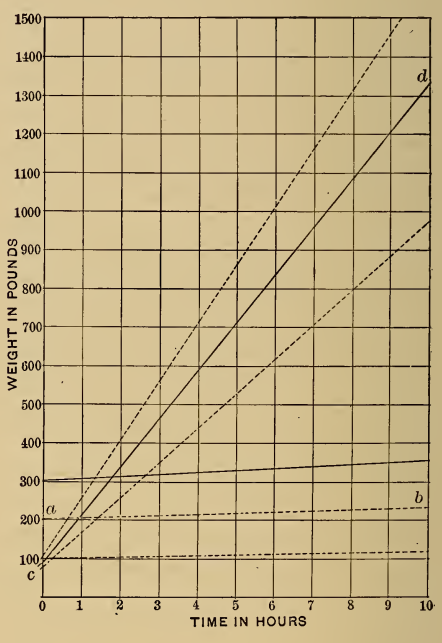
For the purpose of graphical illustration we will omit the items donated by s, and take the initial weights per power-unit. Taking numerical values as above noted, we have for the two equations,

For steam, $w = 200 + 3t$.

For electricity, $w = 90 + 125t$.

These equations are represented respectively by ab and cd in the annexed diagram. The much greater steepness of cd shows how much more rapidly weight increases with time of service for electrical than for steam machinery. It is of interest to note that with the figures chosen, there is the algebraic possibility of making the weights for the two modes of propulsion equal. The necessary condition is a very short time of service, approximating to one hour. The time of service is considered as the time required at the normal rate of running, for the discharge of the batteries.

The ordinary styles of lead cell, however, cannot be advantageously discharged in much less than eight or ten hours. An attempt to shorten the time by increasing the current will result in a loss of total capacity, and if carried so far as to attempt a complete discharge of the cell in one or two hours, reactions would arise which would result in the



destruction of the plates. While, therefore, there is an algebraic possibility of making these weights equal, the necessary condition is one which cannot be electrically fulfilled, and, even if it could, a boat stored with energy for one hour only would ordinarily be of but little use. The most favourable comparison for electrical machinery is, therefore, on a basis of about eight hours service. In such a case we should have for the two weights, 224 and 1090, showing that, at the best, electrical machinery will be about five times as heavy as the equivalent steam machinery and coal. Other

figures might be taken which would vary this in one way or the other, and for short periods of time the output of the batteries might be safely increased so as to reduce this ratio very considerably. The substantial fact still remains, however, that electrical machinery will, under all ordinary conditions, be very much heavier than the steam equivalent. The dotted lines in the diagram represent what may be considered as reasonable limits in both directions for the weights in the two cases.

In the matter of first cost, it will be remembered that with electricity this item depends on time as well as power. Taking eight hours with the cost figures already given, we have for the cost of motor and battery per power-unit, $270. For the steam machinery we should have, for the same unit, the single item of $40. Here, again, there is opportunity for very great variation in figures, yet the fact will remain that in first cost electrical machinery will be much the more expensive of the two.

We have now to note various peculiarities of electrical propulsion, in virtue of which the system will be found to possess certain general advantages as well as peculiar adaptations to special conditions. We first note the decrease in personnel. The batteries need on feeding, and the motor and shafting require but little attention. The services of the fireman and engineer may, therefore, be dispensed with, and it will be sufficient for all ordinary care if the man at the wheel, or some one else on board, has the electrical knowledge necessary to the proper manipulation of the machinery when in use.

As a still further advantage, the motor may be placed under direct control from the pilot house or forward cock-pit. This has been considered as desirable with steam machinery, but, under existing conditions, has proven difficult of practical attainment. With electrical machinery the various grades of power, as well as the reversal in direction, are obtained through the various groupings of a system of switches and resistance coils known as the controller. The combinations of the latter are effected by means of a handle or lever, placed within convenient reach of the man at the wheel, the manipulation of the handle being quite similar to that of the ordinary engine-room telegraph.

We now turn to the question of liability to accident and general deterioration. Disabilities, as a general rule, increase in more or less direct ratio with the increase in the number of moving parts and rubbing joints. We have, in addition, the deterioration of boilers and storage cells, due almost entirely to chemical reactions of one kind or another. In the case of the electric motor the mechanical relations are of the simplest, and the number of moving parts are reduced to a minimum. Mechanically, therefore, the liability of the motor to accident is, with proper design, very small indeed. There is still the possibility of electrical failure, such as the burning out of armature coils, etc., but with proper design and a provision of safety fuses, this liability may be reduced to almost the vanishing point.

Comparing, as a whole, the motor with the engine, it would seem as though the liability to accident and deterioration would be somewhat less with the former than with the latter, equally good design and care being assumed in both cases. As between storage cells and boilers, it would seem fair to consider the electric installation as about the equal of the steam plant in the matter of deterioration. In the matter of dangerous disaster, the liability to fire seems to be about the same in both cases. There remains against the steam installation the possibility of disastrous explosion, a condition of which the electrical installation is entirely free.

Other advantages resulting from the nature of electrical machinery, are the absence of smoke, smoke-pipe, noise and vibration. The absence of a smoke-pipe might be a considerable advantage in running about under numerous low bridges. The question of noise is, of course, relative, but in comparison with steam machinery, the electric motor and shafting may be said to be practically noiseless. The question of vibration is likewise relative, but the amount is very

much less than with steam machinery. The absence of steam for the operation of a whistle and a bilge-siphon may be considered as a slight disadvantage for the electric installation. A substitute for the former is readily found in a whistle attached to a cylinder in which is a plunger worked by hand. For the latter we may substitute a hand pump or some form of rotary pump attached to the main shaft.

In the matter of internal space, the superiority of the motor over the engine and boiler has been already noted. As to the batteries, however, we have seen that they will far exceed coal both in weight and volume. It is, nevertheless, true that for a boat which is intended to run for only ten or fifteen hours, the necessary supply of cells may be stowed away under seats and in otherwise unavailable places, so that no space, otherwise valuable, need be used for their accommodation. It follows that nearly the entire valuable internal volume of the boat may be made available for seating or living space.

As a further advantage we may note that the energy in a storage battery is instantaneously available. There is no delay whatever corresponding to that necessary for getting up steam. This advantage is especially marked for service of an irregular character. The expense, too, continues only so long as there is an actual consumption at the motor. With irregular service the expense will be nearly proportional to the useful work done.

Further, the power admits of rapid and extreme variations. The objections to an extreme increase in the discharging current have been already noted, but for short periods of time such increase may be had without serious results. It thus becomes possible instantaneously to increase the power to perhaps two or three times its normal value, and as rapidly to vary it to any value between this and nothing. This large reserve of power may be of the very greatest value, especially for boats which have to navigate crowded harbours or make frequent landings.

The use of storage batteries for propulsion must, of course, be limited to localities where charging dynamos are available. This, however, is by no means so great a restriction as might at first appear. Electric launches, used as tenders for yachts, men-of-war and other steam vessels may have their batteries charged from the ships' dynamos (assuming their existence on board) when lying at the boom, or when on the chocks.

We have thus reviewed briefly the more important special considerations involved. Taking all things into account, it may be seen that the advantages of electric propulsion may, under certain circumstances, far outweigh its disadvantages. It may be seen to possess special adaptation to the service required of ships' launches and tenders, harbour police and patrol boats, small excursion and pleasure boats, and even small yachts intended for short runs.

From an engineering standpoint, the chief limitation to the extension of this mode of propulsion lies in the excessive weight of the machinery per power-unit developed. This excess is so great with present conditions that electric propulsion cannot compete with steam for either boats powered for very high speeds, or for boats in which a long period of service is required without fresh supply of energy.

Take, as an example, a launch of six tons displacement in which it is desired to put one hundred horse-power on the shaft. With steam machinery this may be done with coal for six hours on about 8500 lbs., and that without going to the extreme of lightness. With the very lightest possible construction of electrical machinery, the weight could not be less than about 40,000 lbs., or about three times the entire displacement of the boat.

Take, as another illustration, a proposition to apply this mode of propulsion to transatlantic steamships. Let the displacement be 15,000 tons, with 20,000 shaft horse-power, provision being made for seven days' total supply of energy. With steam machinery this might be done on about 4400 tons. With storage batteries and motors, the

weight would be in the neighborhood of 150,000 tons, or about ten times the total displacement.

These cases are, of course, extreme, but they are given to emphasize the engineering limitations to the extension of this mode of electric propulsion. The whole limitation arises from the excessive weight of storage cells as compared with coal for equal amounts of work available at the shaft, and so long as the electrical conditions remain what they now are, so long will this mode of electrical propulsion be limited to cases requiring only moderate speed and comparatively short periods of service. Within a somewhat limited field, however, where these conditions are fulfilled, and where the special adaptations may have their full weight, this system of electric propulsion would seem admirable, and we may look with confidence for future extension within such limits.

SOLID FORCE TRANSMISSION.

By Killingworth Hedges.

KILLINGWORTH HEDGES is a well-known English engineer, a member of the Institution of Civil Engineers and of the Institute of Electrical Engineers He has written on several occasions on professional subjects and his name is familiar to many readers of current engineering literature.

THE title of this article is not altogether a satisfactory one, but it is used for want of a better to distinguish between the new method of transmitting energy to be described, and the present well-known arrangements. These may be classified as follows: (1) For long distances, —hydraulic distribution, transmission by compressed air, by steam, by wire ropes and by electricity; (2) for short distances,—steam, hydraulic power, compressed air, shafting and belting, iron rods and chains and electricity.

The methods mentioned in the first class are employed for the practical distribution of energy from central stations, of which it may be well to note some of the principal European examples, as in all large cities there is an increasing demand for mechanical power for the handling of goods, for driving light machinery, and for sanitary purposes such as ventilation and sewage pumping.

Gas engines, which may be said to belong to the first class, in that the working fluid is virtually supplied from a central station, are purposely omitted, but it is only fair to add that in London alone there are nearly 3000 gas engines amounting, in the aggregate, to a considerable power. London has also a fine example of distribution by hydraulic power for the single purpose of working lifts and hoisting machinery. Over sixty miles in length of hydraulic mains are now laid under the streets and the area which can be supplied is constantly extending. This system rapidly became popular, as the following figures prove: In 1884 there were only 96 customers renting power; in 1888 there were 720 consumers, and in 1893, 950, the number of lifts and hoists having greatly increased. At the present time the use of the system is extending more rapidly than at any previous period.

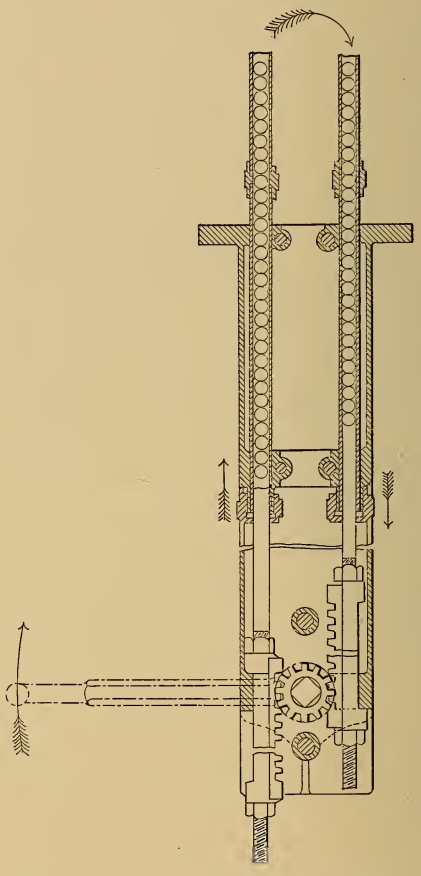
The quantity of water, distributed at a pressure of 750 pounds per square inch, increased from 317,000 gallons per week in 1884, to 600,000 gallons per week in 1892. In no instance has the use of hydraulic power, when once adopted, been abandoned in favour of

any other system for working hoisting machinery. Central stations for a similar purpose have been established at Liverpool, Manchester, Hull and Birmingham. The objection to this method is that the amount of power which can be transmitted by a single main is not very great, thus putting a definite limitation upon hydraulic systems, and making them best adapted for driving machines working only a fraction of the twenty-four hours, and for motors for small industries not requiring a great amount of power.

The hydraulic power supply of the small town of Geneva, Switzerland, is a striking instance of the growth of a demand for this power. In 1871, one factory was driven by water power from the existing low-pressure water mains. The plan proved so convenient that in 1889 a high-pressure system was designed by which the low-pressure turbines, worked by the falls of the river Rhone, supply a high-pressure service to which motors for power purposes are connected, and now some 2000 horse-power is distributed to the consumers for various commercial purposes at a price of one-fifth of that charged in London. The electric lighting station of Geneva also is driven by the high-pressure hydraulic system. Constancy of supply is obtained by means of a large reservoir erected at an elevation of 390 feet above Geneva Lake, and holding a supply for 5573 gross horse-power hours of energy, or about 800 effective horse-power for five hours.

The advantages of the compressed air system appear to lie in the facility for sub-dividing the power and in the fact that the loss by surface friction in the mains is very small. In Paris the original installation was designed by M. Popp in 1881 for the purpose of working and regulating a large number of clocks, but a demand soon arose for a supply of compressed air for working small motors, and this method has proved so successful that there has been developed in Paris the most important system of power distribution hitherto carried out, the principal air mains having an extension of 34 miles.

Great improvements have been made with regard to economy of working, and, whereas originally only 265 cubic feet of air per indicated horse-power hour were compressed to the working pressure of six atmospheres, or about 90 pounds per square inch, 438 cubic feet are now compressed for the same horse-power in the large new compressors at the Quai de la Gare, and the result of working the new station is that a cubic meter of air is compressed to seven



METHOD OF APPLYING POWER TO A SERIES OF BALLS IN TUBES.

atmospheres for about 0.4 centime, or about four-tenths of the previous cost of compression.

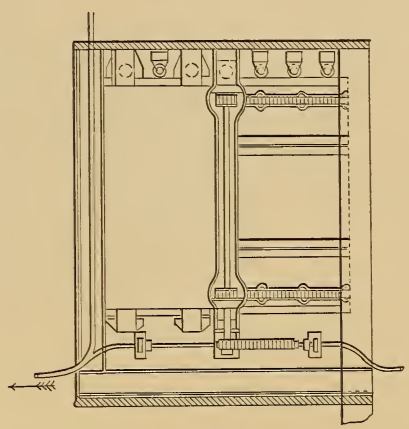
The details of steam power distribution are so well known that it is hardly necessary to do more than point out the

fact that, though it has been tried on a very large scale in the United States, apparently with success, it has not been introduced into Europe so far as the author is aware.

Transmission by wire ropes is perhaps the oldest method of transmitting power, its use dating back to the year 1850, when wire rope was employed to operate some factories in Alsace which were scattered at considerable distances from one another. The stretching and frequent breakages of the ropes at first gave much trouble. The former difficulty was overcome by passing the ropes before use between compressing rollers, and the latter trouble does not occur with the steel rope which has quite ousted that made of iron wire. The Schaffhausen transmission, which utilizes the rapids of the Rhine, still remains the principal European example, nearly 1000 horse-power being constantly employed by the numerous factories by this method alone, quite independently of the electric transmission which has not, as generally supposed, superseded the telo-dynamic method, but has been adopted for the extension of the system on account of the superiority for transmitting power to a considerable distance, thus enabling a larger area to be supplied.

With an electric transmission project as stupendous as that which is now on the eve of starting at Niagara Falls, in the United States, it does not appear necessary to devote any space to the description of the various electric installations which are successfully working in all parts of the world. The experiment between Lauffen and Frankfort, in Germany, showed that it was quite possible to transmit power by electricity over a distance far greater than would be practicable with any other known method. Where the natural forces of great rivers and waterfalls can be utilized, it will often be more economical to waste a considerable amount of power in transit than to pay the large amount of interest on capital invested in the increased weight of wire necessary to secure a higher efficiency in the transformation.

Turning to the second class, embracing methods of transmission over short distances, we find a number of examples in the modern man-of-war which possesses a variety of more or less complicated pieces of mechanism,



SOLID FORCE TRANSMISSION FOR CLOSING BULKHEAD DOORS.

most of which have to be controlled from the upper deck. Some of these, such as the steering gear, the telegraph to the engine-room, and the mechanical devices for reading the speed of the engine, are usually concentrated in the navigation room or conning tower. These various appliances, with the exception of the speed indicators, are worked by steam and hydraulic power in the larger ships, and by rods and chains in the smaller ones.

It is unnecessary to recapitulate these methods. They have, however, suggested the description of a new arrangement for transmission by means of spheres or balls, which the author had the honour of bringing before the Royal Society at London some time ago. The first illustration in this article shows the balls as placed in the connecting tubes. The transmitter and receiver are, to a certain extent, identical. Power is applied by the transmitter to the balls, which may be of small diameter, by means of a plunger, imparting motion, as it descends, to the whole series of balls. These cannot become disarranged, as they are held in position by

a duplicate plunger, which is caused to ascend at the same rate as its fellow descends. Where it is necessary to tap the tube, in order to utilize the power, a similar plunger is inserted, the power being reconverted by means of a pinion and rack as shown on the large scale drawing of the transmitter.

The second illustration is a view of a water-tight door, such as is used on men-of-war. The door is shown open and would be closed by means of the balls in the tube, which can also be led so as to perform any other similar work at the same time. It is proposed to instal the transmitter in the conning tower so that, in the event of any urgent necessity arising, all the doors in the ship could be closed at once. Each apparatus would also act as an indicator in the event of an order having been issued to close the bulkheads by manual labour, which could be effected by a simple attachment to each door.

There are a variety of applications for this simple device, which can be easily applied in positions on board ship where, at present, hydraulic power is used. The latter method, though doubtless efficient, is complicated and would be very liable to derangement during an action, whereas it is difficult to see what accident could interfere with the series of balls if the tubes in which they are contained are sufficiently protected. If this precaution were observed a thin tube could be used, the tendency to burst the tube being almost nil, the only strain in that direction taking place at the bends. Each ball has a crushing strain of over 15 tons, which is far in excess of any pressure which could be brought to bear.

The question will naturally be asked, what is the loss? To this, unfortunately, no answer can be given. In the experimental tubes, which were of a length sufficient to communicate between the bridge and steering gear of a ship, there was a very high efficiency, but the methods of tapping the tube to utilize power at various positions were not sufficiently developed to allow of accurate measurements being taken. It is an interesting experiment which can be tried by any engineer as, thanks to ingenious American machinery, steel balls can not only be turned out accurately, but at a very low price.

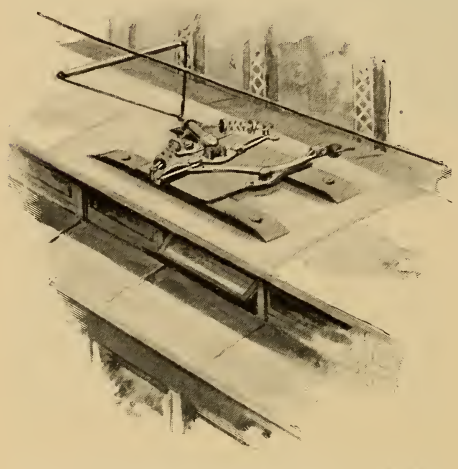
Current Topics.

THE desirability of cleanness in an engineering workshop, of picking up every chip, and of sweeping in every nook and corner has been so much talked about within the past few years, that scarcely any one possessing an ordinary shop is without a twinge of conscience every time he sees a little dirt heap. Practically, however, the exact degree of cleanness which is the most economical is a subject which might be profitably discussed. In a dark shop it is best, of course, to have the windows as clean as soap and water will make them, but where rough work is going on, there would seem to be little use in trying to imitate some of the shops where only the finest work is done. If it is a question of making fine tools, gauges, and nice work generally, cleanness is certainly desirable, but when it is repair work on big engines and the like, it is not probable that the shop owner can effect any increase in his income by attempting to have everything "spick and span." In one of the best-known shops, where litter is never allowed to accumulate, it is quite interesting to study the conditions of the different departments. On one of the upper floors, where the work to be done is delicate and where the light is, of necessity, very good, everything is as neat and clean as one could wish, but in those departments where the heavier and coarser work is carried on, there is no attempt to approach any such neatness. Every department has its own standard, and that standard is adjusted to the requirements of the work. The degree of cleanness and neatness, then, is to be determined by the money basis. That degree which will pay is the degree which a shop ought to support.

FOUNDATIONS for machine tools are as important in their way as foundations for any other important structure, and, in more than one instance, have been found to be at the root of perplexing difficulties. In one case that was brought to light some time ago, a large planer, resting on an apparently firm foundation of many courses of stone and brickwork, habitually gave trouble by getting out of line. After having trued it up as carefully as possible, it would do very good work until a particularly heavy piece had been finished upon it, and then it was usually found that ways, frame, foundation and all had settled under the load, and that lining-up had to be resorted to again to get things

into shape. In this case the trouble was looked for and discovered in the circumstance that the works stood upon land that had been filled in, years ago, it is true, but still the subsoil had not been sufficiently compacted to properly sustain a large, concentrated load.

ONE of the features of the train service on the big bridge connecting the cities of New York and Brooklyn which



CAR-LIGHTING TROLLEY ON THE NEW YORK AND BROOKLYN BRIDGE.

at once attracts an engineer's attention is that while the cars are hauled by cable, they are lighted electrically by an overhead trolley arrangement. When the new lighting system was first introduced, a few months ago, ordinary trolley poles and wheels were used on the cars, much after the method practiced in the equipment of regular electric street cars, except that the length of the poles was, for specific reasons, reduced to about two feet. With this short pole it was found, however, that the trolley wheel would not well remain on the wire, especially at switches, and pole and trolley wheel were, therefore, abandoned for the arrangement shown herewith, which, in all essential respects, is modeled after the practice on several European electric railroads. The appliance consists of a wire frame, of which the upper part, bearing against the supply wire, carries a brass roller about 18 inches long. Owing to the shortness of the distance between the wire and the car roofs there are no poles whatever, and the wire frame is held directly in the pole socket of the trolley base.

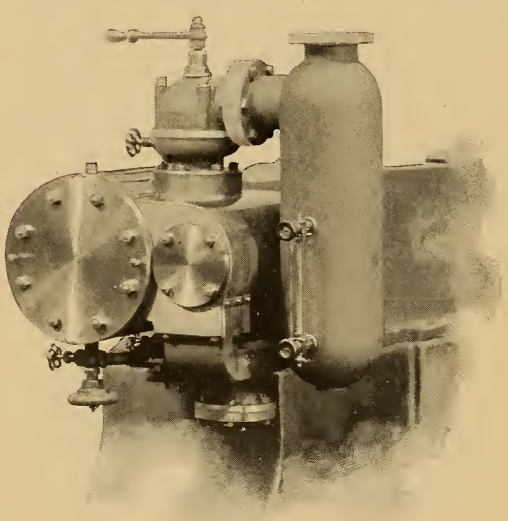
UTILIZING the heat contained in slags from smelting furnaces furnishes another example of the profitable turning to account of a waste which, in some cases, may be of important proportions. Of all purposes to which such heat could be applied, that of the raising of steam is probably the most directly useful and possible and not a few experiments have, accordingly, been carried out with that end in view. In some of these at Broken Hill, in New South Wales, as detailed in a paper presented some time ago before the Australasian Institute of Mining Engineers by John Howell and E. A. Ashcroft, the method was tried of applying water direct to the molten slag in a confined space, and for this purpose a trial machine was put to work in connection with a small hydraulic pressure supply which was designed for manipulation of the various parts of the machine. Difficulties were here met with, owing to the formation of non-conducting crusts of cooled slag, and the condensation of the steam by the feed-water coming in from above. After many modifications, the feed-water was introduced below the molten slag, and, passing upward, it was supposed, would keep the whole molten body in circulation, and prevent the formation of crusts, impervious to heat. This machine, although a considerable improvement on the former ones, failed to thoroughly extract the heat from the slag within the limits of the time available, and it became evident that the real difficulty in the way of this form of treatment was the spheroidal state assumed by liquids in contact with very hot surfaces. This phenomenon retards the passage of heat from the slag to the water to such an extent that, contrary to all expectations, the transfer of a

given quantity of heat will require several times as long to take place when the temperature of the imparting body is above the critical temperature at which the spheroidal state sets in and a film of non-conducting dry steam intervenes between the spheroid of water and the heat-giving body, as will be required for the same result when the temperature is below that point, in which case the water remains in actual contact with the heat-giving body. This limit of temperature in the case of water and slag was roughly determined as between 500 and 700 degrees Fahrenheit.

MESSRS. HOWELL AND ASHCROFT therefore discarded the direct-contact method in favour of a method of imparting the heat to the water through the medium of a metallic casing. The slag, according to this, was poured into vertical wrought iron or copper tubes, surrounded by water for nearly their entire length. The tubes were made taper, with the larger ends below, and closed by cast iron doors so arranged as to be readily opened and closed from above. The tubes were surrounded by a shell of steel and this was fitted with a steam dome, safety valve and other regular boiler mountings. A simple wrought-iron truck passed beneath the boiler on rails and received the contents of the tubes. One such boiler at Broken Hill, taking the slag from one furnace, yielded about 60 horse-power and effected a most important saving in the running of the plant. Similar boilers can, obviously, be used wherever molten slag is discharged from furnaces.

MODERN high explosives are again bringing the principle of the old gunpowder engine into prominence. Col. Barker, superintendent of the British Royal Small Arms Factory, at Sparkbrook, in recently speaking of the subject, made the point that while one pound of gunpowder was capable of developing over 170,000 foot-pounds of energy, the new smokeless powders were capable of still more, and, at the same time, left no solid residue as ordinary gunpowder did on combustion. The latter, too, developed, in combustion, only about 280 volumes of permanent gases, while the new powders gave off nearly 1000 volumes. With this encouragement it is not at all unlikely that the gunpowder engine inventor will set to work with renewed enthusiasm.

STEAM separators have, in recent years, become important adjuncts to the equipment of every carefully laid-out steam plant, and a multiplicity of forms of this class of apparatus has been put on the market, each performing its share of good work. One of the most recent of the designs, brought out by the American engine builders, A. L. Ide & Son, of Springfield, Ill., is in the

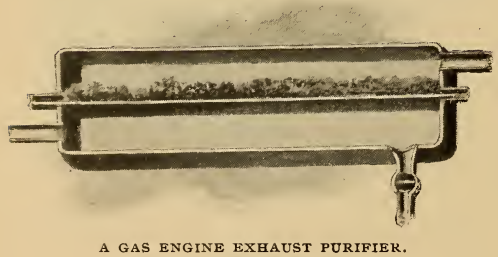


A COMBINED THROTTLE VALVE AND STEAM SEPARATOR.

shape of a combination apparatus,—a combined separator and throttle valve, the two being united to each other and to the steam pipe leading to the engine by flanged connections which can be easily taken apart so as to give access to the valve. The separator is thus brought close to the engine and serves only that one engine, instead of being some distance off in a main pipe from

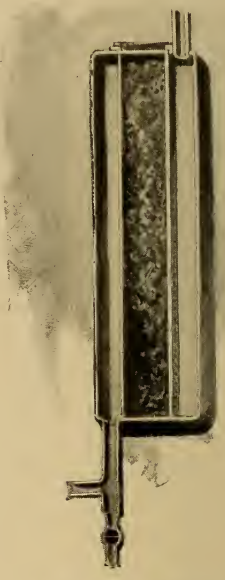
which several branches lead to as many different engines as is frequently the case, and the results, in point of dry steam, are correspondingly more satisfactory. The apparatus is compact and ought to commend itself to engineers.

THE noise and odour of oil and gas engine exhausts are objectionable features with which everyone who has used motors of this type is quite familiar. Oil engines, particularly, are more or less offensive in so far as the odour of the escaping waste gases is concerned, so that means, designed to overcome this difficulty, are of interest to a rapidly growing number of people. One of the latest deodorizing attachments, brought out in France a short time ago, is shown in the annexed sketch, and is altogether a very simple little device which, at the same time, would seem to promise good results. Its principle of action depends upon the absorbing properties of bone-black, or the affinity which this substance has for certain other substances, among them the objectionable components of the combustion gases from oil engines. The bone-black, as used in the device, is, moreover, made to exercise a double



A GAS ENGINE EXHAUST PURIFIER.

effect,—acting by absorption as well as in a mechanical way, by filtration. The apparatus consists of nothing more than a box, divided into two compartments by a perforated partition on which the bone-black is spread in a moderately thick layer. The exhaust gases from the engine enter into the lower compartment at the extreme left, pass through the perforated dividing wall and superimposed layer of absorbent into the upper compartment, and thence escape into the open air through the pipe at the upper right-hand side. The ammonia and fetid hydrocarbon gases are absorbed by the bone-black, and whatever liquid offensive particles may be in the products of combustion are retained by it mechanically. Water of condensation, which is apt to collect in the lower compartment, may be drained off through a drip pipe, as shown.



A VERTICAL PURIFIER.

A SIMILAR device has been made in a vertical pattern in which the bone-black is held in a middle compartment with perforated walls. The exhaust gases in that case are made to enter at the bottom into the left-hand space, and can reach the escape pipe in the right-hand compartment only by passing through the intervening bone-black filter. A drip-cock and pipe are again provided for drawing off accummulations of water of condensation. The contrivance is simple and evidently inexpensive, and would seem worth trying.

THE importance of the speed of cutting tools as a factor in machine shop economy referred to, among other things, in Mr. Oberlin Smith's article elsewhere in this number, calls to mind the remark, overheard some time ago, that it would very likely pay the makers of emery wheels to join in the permanent employment of a sensible traveling man to visit, periodically, every user of such wheels with the view of

assuring that every wheel would be kept up to its proper speed during the time when the work to be done was actually on it. There is an almost endless number of wheels in use, it was stated, which do not run within a third of the proper speed at which they should be kept, and it was held to be equally true that there is generally no one about who can tell, or who looks to see, whether or not the wheels are kept to this speed. One of the most general hindrances to the maintenance of full speed is the want of a solid, massive floor or pier for the wheel and its frame to stand on while running. A light floor or bench often permits an excessive jarring of the whole vicinity when a wheel, standing upon them, is started and fear is naturally awakened that something may give way. This leads generally to an intentional slackening of the speed by a change in the sizes of the pulleys, sometimes excused with the assumption that if a wheel at full speed does a certain amount of work, it will do, say, nine-tenths as much when the speed has fallen off one-tenth. This, however, is far from being true. A comparatively small loss of speed below the standard can, in fact, be shown to prevent the wheel from doing any work whatever worthy of the name. Another reason for tolerating a serious loss of speed is that in many cases a much greater amount of power is found to be consumed in the running of the wheels than had been expected and provided for, and the wheels are, therefore, suffered to go a little by default lest other parts of the shop should be left with scant speed for the work which they must do. And, yet, the fact remains that a wheel which is not persistently kept to the uttermost speed which the strength of its own substance will permit is scarcely worth the room that it occupies in any establishment.

Mr. Smith, in the article referred to above, where he speaks of cutting tool speeds, draws simply a picture that many have seen before. In one shop where, perhaps, the men are paid by the day and where contract work has never been heard of, one may see good-sized machines turning off fine shavings which look more like bits of hair than chips of cast or wrought-iron, and one will there reach the conclusion that the particular metal worked on is of a tremendously hard and intractable nature. If, after this, one will step into a shop where contract or piece work is the rule, one will be very strongly impressed with the idea that they do not use common cast and wrought-iron there, but are dealing with very much softer metal. Tools go ripping through the work as though it were only hardwood. There is a lesson in all this, tending to show that the question of the best speed for a lathe, planer or milling machine is one which is gauged by the pounds, shillings and pence marks rather than by feet per minute.

An ingenious solution of a problem which occurred some time ago in connection with the extension of the water-works plant of one of the smaller towns in the southern part of the United States, was recently described by Mr. C. H. Ott before the Engineers' Club of Philadelphia. The works in question consisted of a well, 10 feet in diameter, driven to a water-bearing stratum 80 feet below the surface of the ground, and containing a double-acting, single-cylinder pump, located about 15 feet above the bottom of the well and worked from the pump house above. As the water required at the time when these works were established was not very heavy, the supply from the well in six hours of pumping was sufficient for 12 hours of service, and the engine and pump had sufficient capacity to empty the well within 8 or 10 feet of the bottom in about 12 hours of continuous working. When it became necessary to repair or examine the pump cylinder, the water was lowered by pumpage to the greatest possible extent, and then, by means of a steam jet, the well was kept drained.

As the town grew, the supply from the well became inadequate, and a new

well was started about 40 feet east of the pumping well. A shaft 6 x 12 feet was driven to a depth of 120 feet, where a flow of water was had. In order to provide storage for water, and to connect the new shaft with the pumping well, a timbered drift, 4 x 6 feet, was run to directly beneath and about 40 feet below the bottom of the pumping well. The water supply not yet being deemed sufficient, an 8-inch well, cased with pipe, was bored in the new shaft to a depth of 230 feet below the pump house floor, and a great flow of water was struck. The drill, in passing through the disintegrated limestone, bored a much larger hole than 8 inches in diameter, so that large quantities of water passed up outside of the casing. When the depth of 230 feet was reached, the latter quantity was so great that the water level in the new shaft could not be lowered and maintained with the apparatus at hand to more than about 20 feet below the pump house floor. An 8-inch hole was then drilled from the bottom of the pumping well to the drift below. It was still found impossible with all of the pumps and jet apparatus available to lower the water level in the pumping well to more than about 25 feet below the pump house floor, thus furnishing an ample water supply.

SOME months after these arrangements had been finished, a failure occurred in the pump cylinder, under 50 feet of water, and with no apparatus available to lower the water in the well sufficiently to make the necessary repairs. After several expedients had been tried the following contrivance was devised :—A balloon-shaped bag, about 3 feet in diameter and 6 feet long, was made of six plies of bed ticking, roughly quilted into squares. The bag was soaked in linseed oil, and a quantity of rye flour was inserted and well shaken around. A 1-inch pipe, terminating in a sleeve, was inserted in the mouth of the bag, which was then securely wired around the pipe. Sewn to the bottom of the bag was a stout ring and to this was wired a half pig of iron by a ring bolt, inserted into its end. The bag was then wrapped tightly with twine into a cylindrical shape and was lowered into the drill hole in the pumping well by means of sections of pipe until the weight struck bottom, by estimation one half of the bag entering the drift below, the remainder being in the drill hole. The 1-inch pipe was then attached to the service main through a stop cock and a pressure gauge attached thereto, and the bag was slowly distended until a pressure of 50 pounds per square inch was reached and maintained. The upper part of the bag swelled out and accommodated itself to the irregularities of the drill hole ; the lower part of the bag swelled out into a bulb shape, the whole resembling an inverted champagne bottle cork. The drainage pump and steam jet were then set to work and speedily emptied the pumping well, the bag being held in shape during the lowering of the water by an interior water pressure of about ten pounds per square inch in excess of the exterior water pressure. The repairs to the pump having been readily made, the water was exhausted from the bag and the apparatus withdrawn. As the materials not already on hand could only have been obtained by express in about forty-eight hours, and as the contrivance described was easily made and did the work so quickly that the pumping engine was stopped only about ten hours, the treatment of this problem was a most ingenious and clever solution of what threatened to be a serious condition of affairs for that neighborhood.

WITH the several noteworthy repairs fresh in mind that have, of late, been made and described in the cases of broken-down machinery at sea, it is interesting to recall an experience of older standing, which occurred on a steamer in Eastern waters a number of years ago and which is quite as illustrative of ready engineering expedients as any of later date. On the ship in question, while going at full speed, the engines suddenly gave a loud crack, as if something had burst, and then came

to a stop. The chief engineer hurried into the engine-room and examined everything without finding any cause for the accident. The valve casings, too, were inspected without any clue to the trouble, but on taking off the low-pressure cylinder cover, a hole was discovered in the side of the cylinder, measuring about three feet square, and the pieces of metal from the wall were found lying on the top of the piston. The weather being squally, no time was to be lost, and the happy idea occurred to the chief engineer to make a wooden patch, which he proceeded to do by first getting a piece of wood, two inches thick and six inches wide, which he put between the jacket and the cylinder face, bedding it close at both ends and holding it by means of countersunk screws through the cylinder face. Six such pieces were put in and secured in this way, and then some hardwood was used to make the recess still remaining flush with the working face of the cylinder, the hardwood being screwed to the six-inch pieces first mentioned. Only seven hours were taken up in making this ingenious repair, and, the cylinder cover being put back in place, the engines were tried with about forty-five pounds of steam and were allowed to work at half speed until the steamer was brought safely into port.

SEVERAL interesting examples of traction engines are, at present, in use in the Nevada lumber regions, in the western part of the United States, hauling lumber to the town of Verdi from saw mills in the mountains. The lumber is loaded on heavy wagons, from 4000 to 5000 feet to the wagon, and from eight to ten of these wagons are coupled to each engine. The greater portion of the lumber comes from a distance of about seventeen miles, and the round trip is made in a day, the engines leaving Verdi in the morning with empty wagons, and returning in the afternoon with loads. As much as 58,000 feet of lumber, loaded on twelve wagons, have been brought in at a single trip with one of these engines, but the average is about 40,000 feet per trip. The road over which the engines travel is an ordinary mountain road with many up and down grades. One grade, on the outward trip, is two and one-quarter miles long with a rise of 1320 feet to the mile, and on the return trip is another, of equal length, with a somewhat lighter grade. The engines, which were designed by R. R. Doan, of Verdi, weigh from 16 to 24 tons, and the entire weight rests on three wheels, all drivers, one in front and two in back. The front

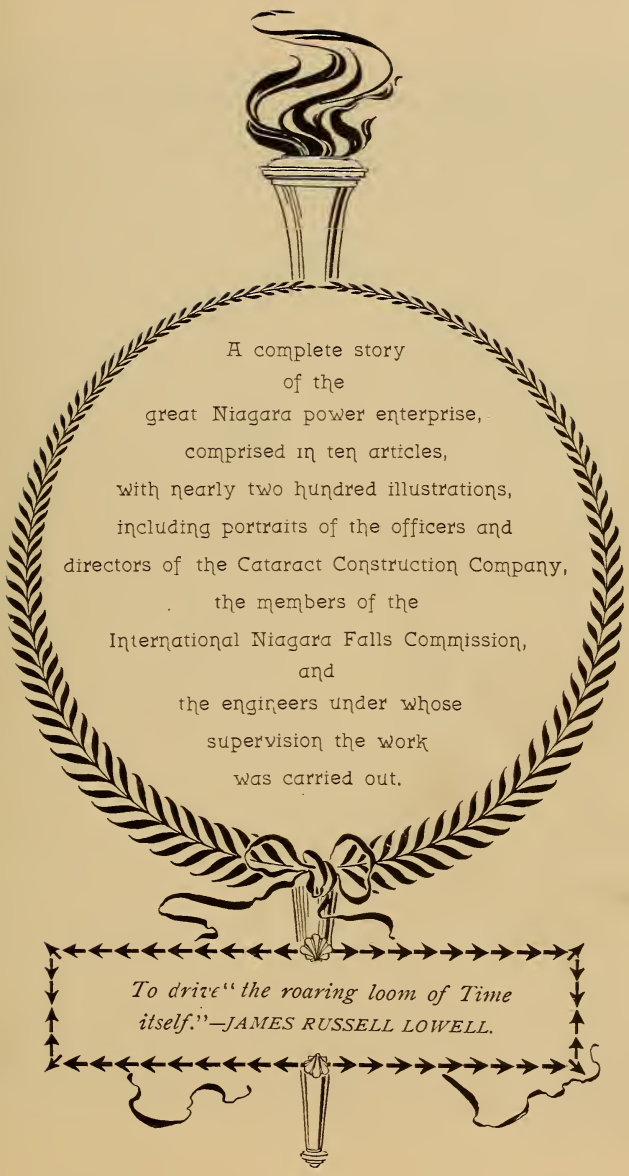
A TRACTION ENGINE IN THE NEVADA MOUNTAINS.

wheel serves also as a steering wheel. In California, too, traction engines have, of late, found a more extended application, and one firm, the Best Manufacturing Company, of San Leandro, have built a number of them which are now performing various services, hauling lumber in the rough mountain districts, as well as general freight trains over ordinarily good country roads. One train is now in use in hauling salt a distance of thirty miles over the desert in San Bernardino county from the mines to Danby, a point on the Atlantic and Pacific Railroad, to be shipped to different points. This route is somewhat sandy. The train, however, makes the round trip of sixty miles in a day and a half, including loading and unloading. The cargo averages about

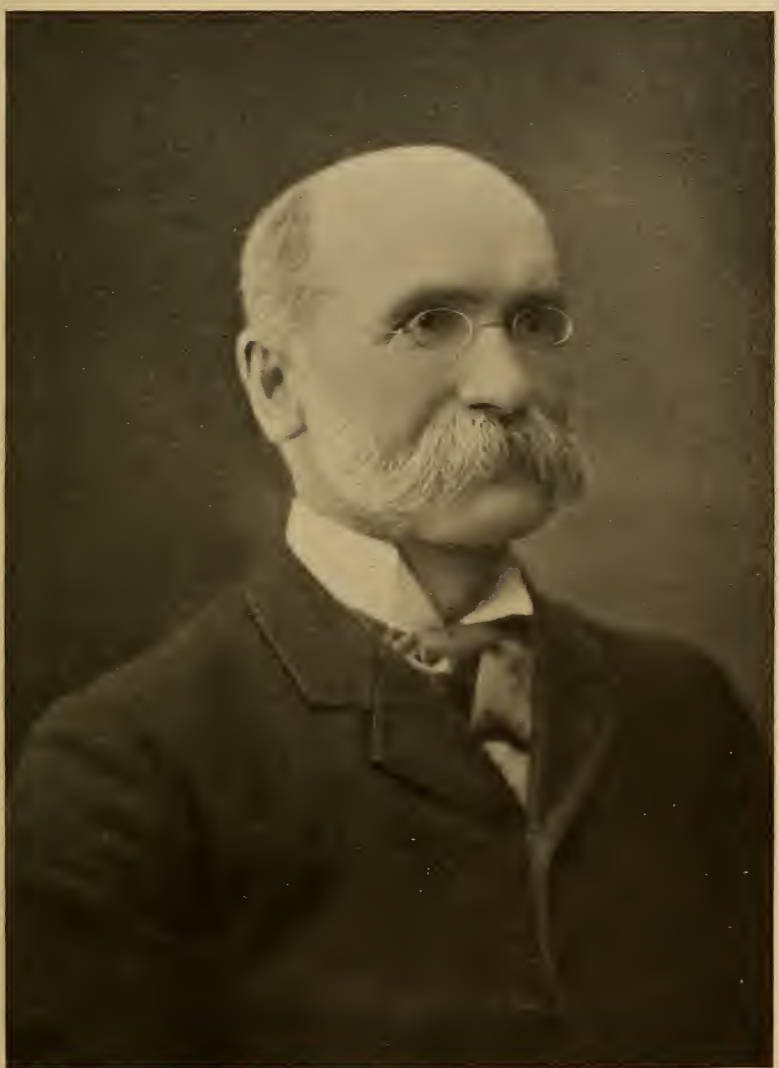
forty tons at each load. How trying a field of work this is for traction engines will be better appreciated when it is called to mind that much loose sand is encountered in the roads and that water is very scarce, so that the engine must haul a sufficient supply from one end of the line to last for the whole trip. Still, the traction engine train is a success there and makes it possible to market one of the great resources of California that otherwise would lie dormant for want of way of getting it to a shipping point on the railroad.

ANENT the subject of high evaporative power of steam boilers which is given prominence with nearly every new boiler design put on the market, it seems worth recalling the pretty well thrashed-out point that all the water which is pumped into a boiler does not necessarily leave it in the shape of steam. Moisture percentages in steam always will command attention and generally explain away much of the wonderful about extraordinary claims of performance. During the Centennial Exhibition at Philadelphia, in 1876, there was, it is said, a standing joke in regard to a boiler which evaporated 19 pounds of water per pound of good anthracite coal and which, the inventor thought, could do 20 if it had a fair chance. There was, of course, the question whether the apparatus ought to have been called a steam boiler or a steam pump, since the quantity of water which could be passed through it apparently depended more on the quantity of feed than on the amount of fuel consumed.

THE specification of the United States patent, numbered 536,360, and dated March 26, 1895, is an interesting bit of literature, having been designed to actually secure legal protection for the very simple method, proposed years ago, of enabling two railroad trains to pass each other on the same track without collision. The frequent attempts of trains to thus pass each other have been attended so uniformly with disastrous consequences, that the feat has become pretty generally recognized as an impossible one, and most engineers have concluded to desist from further efforts to accomplish it. The plan now proposed in all seriousness seems to be the exact counterpart of the one which, in a spirit of levity, was mentioned in these pages in November, 1893, and of which the appended particulars may be of renewed interest at the present time. The idea is, altogether, very simple, as most really great plans and ideas are. The inventor of earlier years proposed, as the present one does, to place on the front of every locomotive going in one direction, a long inclined plane, and on this were to be two rails. These were to come close to the regular track at the forward and lower end of the plane, and at the upper end were to be connected with other rails running along the tops of the cars and down to the main track again on another inclined plane at the rear end of the train. When the train provided with this attachment would meet another train on the same track, the latter would simply go over the former, its weight making the connection of the front of the inclined plane and the rails on the main track perfect, and acting, at the same time, as a brake on the speed of the train underneath. It is, of course, perfectly evident that if this invention had been properly appreciated and generally adopted, the number of double-track roads the world over would not now be half as great as it is. A single track, with occasional switches for heavy freight trains, would have answered all purposes, and the cost of building railroads would have been decreased by an important percentage. However, it is not too late to make up for lost opportunities. We may still live to see the system adopted on all single-track roads so that, before very long, the sensation of riding over or passing under another moving train may become so common as to pass almost unnoticed.


A complete story
of the
great Niagara power enterprise,
comprised in ten articles,
with nearly two hundred illustrations,
including portraits of the officers and
directors of the Cataract Construction Company,
the members of the
International Niagara Falls Commission,
and
the engineers under whose
supervision the work
was carried out.
To drive "the roaring loom of Time
itself."—JAMES RUSSELL LOWELL.

Edward D. Adams.

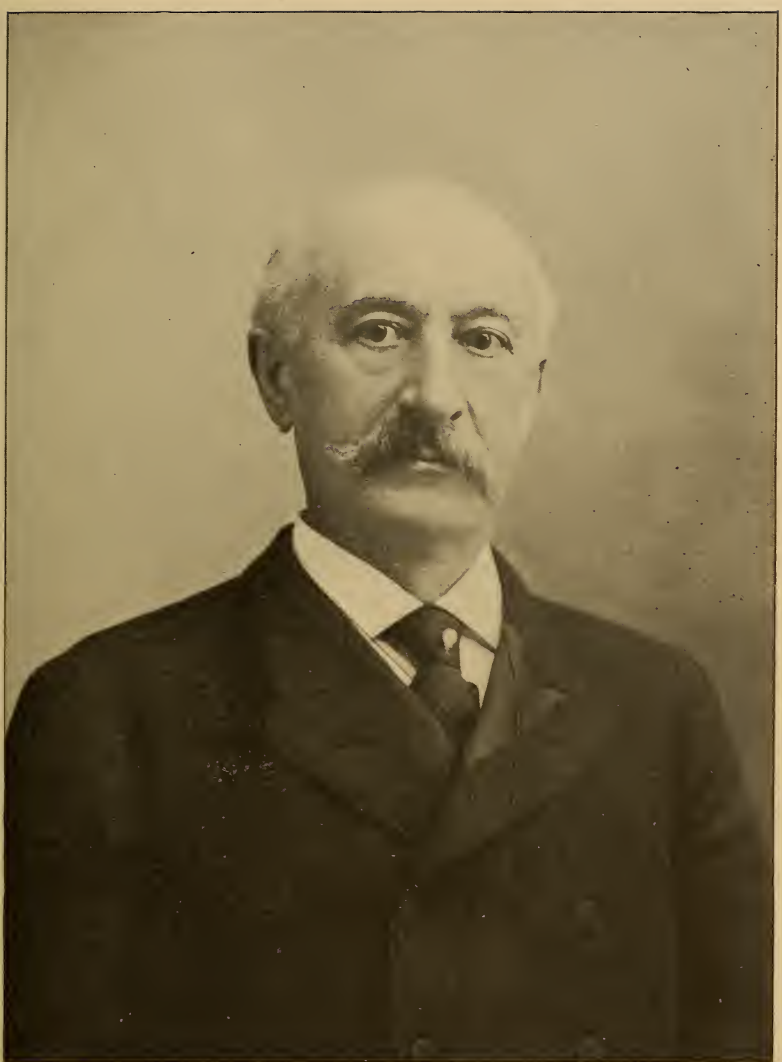


Charles F. Clark

JOHN JACOB ASTOR.

GEORGE S. BOWDOIN.

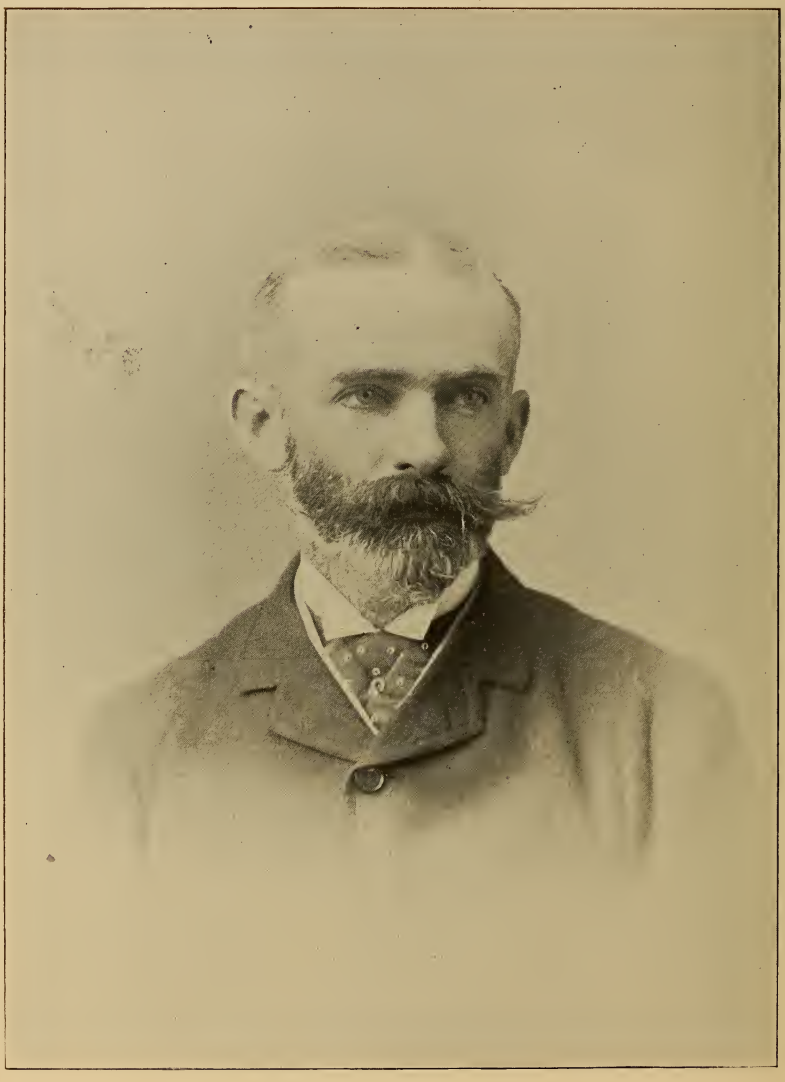
Charles Lanier



B. Larocque

D. O. Mills

W. B. Rankine



F. W. Whitridge

Edward A. Hicks

F. L. Stetson

FRANCIS LYNDE STETSON is the first vice-president of the Cataract Construction Company, and, as such, is among the best qualified to present a general and comprehensive account of the use of Niagara water power.

Niagara Number.

CASSIER'S MAGAZINE.

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THE HORSESHOE FALLS.

THE USE OF THE NIAGARA WATER POWER.

By Francis Lynde Stetson.

SINCE Father Rageneau, in 1648, wrote to his Father Superior concerning Niagara, "a cataract of fearful height," spectators by the million unconsciously have revealed something of themselves in various efforts to disclose to others the essential character of the Falls of Niagara, confessedly incomparable with any other natural object. To souls sensitive to the beautiful and the sublime, the plunging torrent has appealed by the stateliness of its stream, the brilliance of its boisterous rapids, and the deep glassy green of its silent foreboding brink, as well as by its drop into the seemingly infinite depth, from which there comes to him who listens the note of the welcoming abyss, deeper than the diapason of any organ's pipe.

To most, the first impression, and to many the enduring impression, is that of awe, in which the subjective mood prevails and a certain sense of personal danger dominates all other thoughts of this mighty moving flood, pouring resistlessly down through the gorge, which, for itself, it has forced through multiplied strata of rocks of many ages. Danger there certainly is, and death in this resistless, remorseless tide has been

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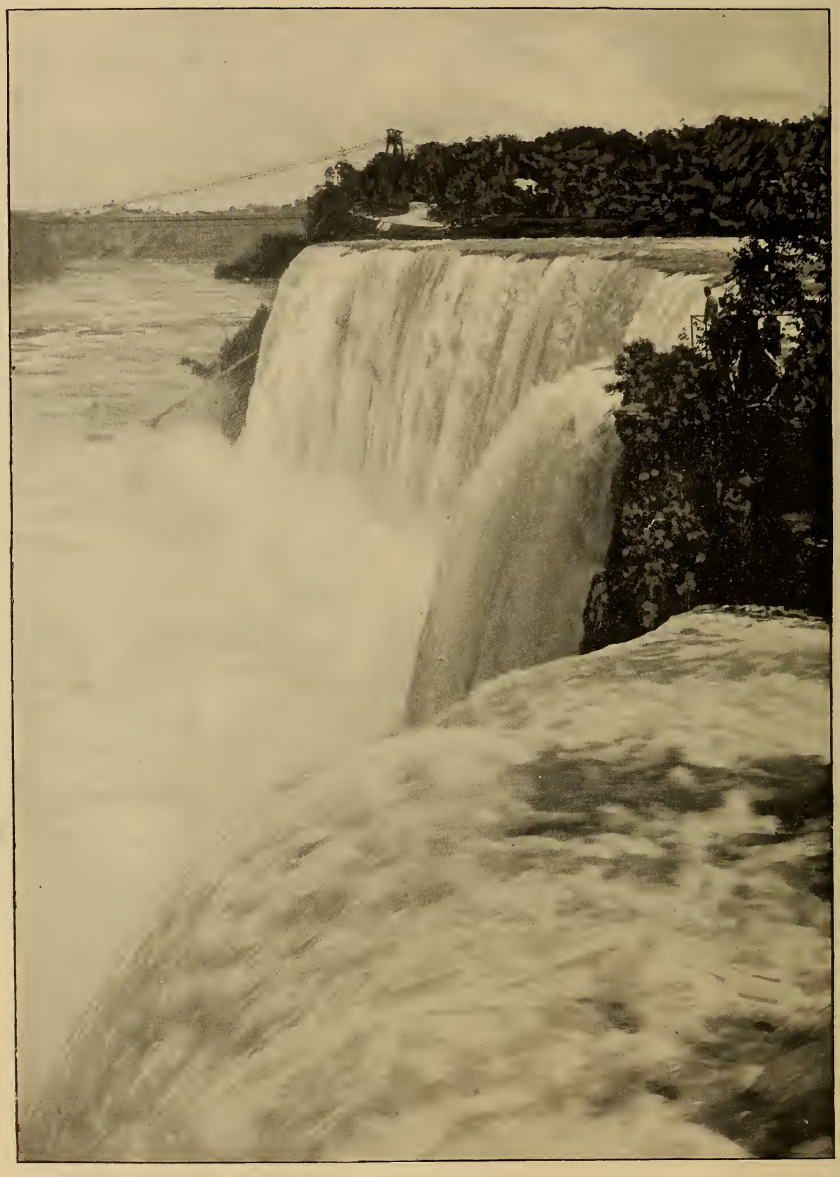
THE FALLS FROM PROSPECT POINT.

found and also has been sought by hundreds; but notwithstanding its appalling aspect, it is through this very sense of resistless power that the Falls speak to minds of great dignity and self-restraint, and lead them to observe as did Mr. Carter of New York, in his characteristically fine oration at the opening of Niagara Park, that the "sense which responds to this magnificent motion" is the "sense of power."

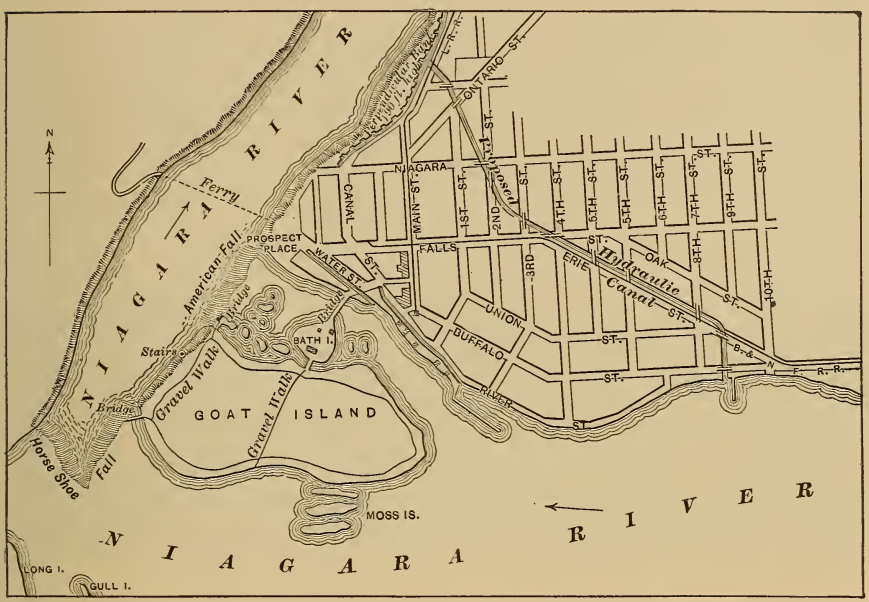
And why should it not be so? Nearly 6000 cubic miles of water, pouring down from the upper lakes with 90,000 square miles of reservoir area, reach this gorge of the Niagara river at a point where its extreme width of one mile is by islands reduced to two channels of only 3800 feet. Here, in less than half a mile of rapids, the Niagara river falls 55 feet, and then, with a depth of about 20 feet at the crest of the Horse Shoe Falls, plunges 165 feet more into the lower river. The ordinary flow has been found to be about 275,000 cubic feet per second, and in its daily force, equal to the latent power of all the coal mined in the world each day—something more than 200,000 tons.

This natural comparison at once suggests, as through the century it has invited, an estimate of this power in the terms of mechanics, and it has been computed by Professor Unwin that these falls represent theoretically seven million horse-power (others think more), and for practical use, without appreciable diminution of the natural beauty, several hundreds of thousands of horse-power. The idea of subjecting to industrial uses some part of the enormous power of Niagara Falls has, since the location of the pioneer saw-mill in 1725, occupied the minds and stirred the inventive faculty of engineers, mechanics and manufacturers. Early in the century, the pioneers in the locality, to which

A VIEW OF THE OLD MILLING DISTRICT.



FROM GOAT ISLAND, LOOKING TOWARDS LUNA ISLAND.

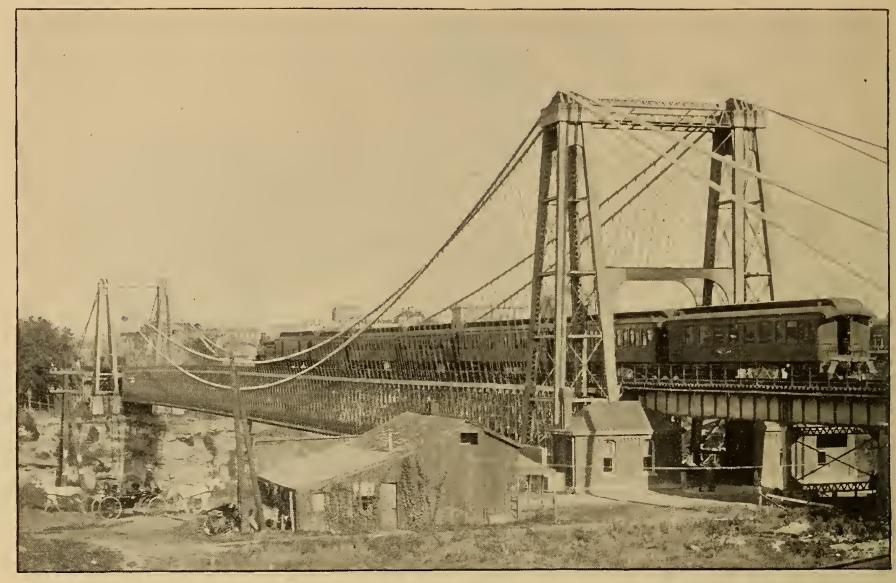


PETER EMSLIE'S MAP, SHOWING THE EARLY CANAL AND RESERVOIR PROPOSED IN 1846.

they then gave the name of Manchester, contemplated the probability, but were unable to demonstrate the practicability, of reducing this mighty force to obedient and useful service. They dwelt upon, and to some extent exploited, the idea; but before the development or adoption of any method promising satisfactory returns, steam and steam engines had properly attained such a place in the favourable estimation of manufacturers that water-powers in general, and especially those inconveniently situated and variable in quantity and quality, fell into comparative disesteem.

The economical production and distribution of coal for use in connection with the engines developed by the genius of Corliss and his fellows, naturally led manufacturers to prefer to produce their own power at their own homes or in proximity to favourable markets, rather than to set out in search of remote and uncertain water-powers. But some water-powers were operated and continuously employed, notwithstanding, and even during, the steady development of the advantages of steam power. No one needs much persuasion to admit that, except for the decided merits of water-power even in competition with steam, the names of Manchester, Lowell, Lawrence, Holyoke, Paterson, Cohoes and Minneapolis, in the United States, would possess nothing like their present significance.

In view of the obvious advantages offered by water-powers such as these, Augustus Porter, one of the principal proprietors at Niagara, in 1842 proposed a considerable extension of the system of canals or races then employed, and in January, 1847, in connection with Peter Emslie, a civil engineer, he published a formal plan, which became the subject of negotiations with Walter Bryant and Caleb S. Woodhull, formerly Mayor of New York. An agreement was finally reached with these gentlemen by which they were to construct a canal, for which they were to receive a right of way, 100 feet in width, together with a certain amount of land at its terminus. After various interruptions, in 1861, their successor, Horace H. Day, completed a canal, about 35 feet in width, 8 feet in depth



THE NIAGARA FALLS RAILWAY SUSPENSION BRIDGE.

and 4400 feet in length, by which the water of the upper Niagara river was brought to a basin or reservoir at the high bluff of the lower river, 214 feet above the water below. Upon the margin of this basin have been constructed various mills, to whose wheels the water was conducted from the canal and discharged by short tunnels through the bluff into the river below, so that in 1885, about 10,000 horse-power, substantially the available capacity of the canal, was in use.

In that year there happened to be at Niagara an able and experienced engineer, engaged in the State's service in laying out a proposed reservation, just as nearly 50 years before he had been there engaged in assisting the State Geological Survey of Prof. James Hall, who, in his report on the Niagara river district for 1843, specially mentions the services of Thomas Evershed. During this very long interval, Mr. Evershed had been engaged as a public engineer, usually upon the Erie canal in that vicinity, and it was natural that he should be called upon to devise a system for the development of hydraulic power from the river with which his whole professional career had been associated, his last great work being in connection with the effort to protect Niagara, in its principal character as the most magnificent and impressive terrestrial natural object, from vandalism and utilitarian desecration. This protection of the natural beauty of Niagara was the underlying idea in his conception and development of his plan, which contemplated the taking of water and the development of power in a district more than a mile above, and out of sight of the Falls, with an outlet tunnel discharging inconspicuously at the river's edge below the Falls, involving the diversion of less than four per cent of the total flow of the river, and a reduction of the depth of the water at the crest of the Falls by less than two inches.

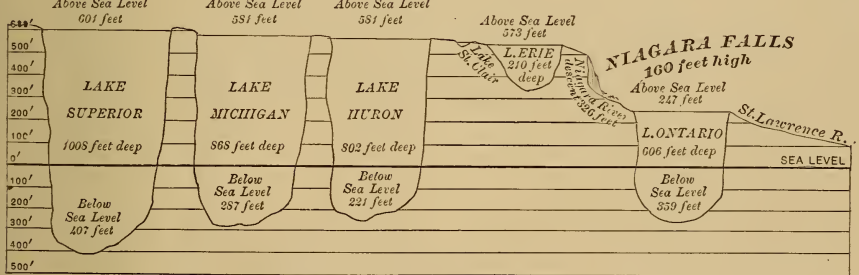
After conference with Mr. Evershed, Capt. Charles B. Gaskill, the oldest user of power on the hydraulic canal, with seven other gentlemen of Niagara Falls, obtained from the legislature of the State of New York, a special charter, passed March 31, 1886, which has since been amended and enlarged by several successive acts. Upon July

1, 1886, Mr. Evershed issued his first formal plan and estimate, which was considered worthy of discussion in Appleton's Cyclopædia for 1887, where it is described in general terms. But, of course, the publication of this plan invited and encountered the demonstration of its absolute impracticability, as well as the improbability of the use of the power if developed. In Bradstreets, October 30, 1886, appeared a letter from Mr. Edward Atkinson (completely answered by Mr. Clemens Herschel on November 6, 1886), undertaking to show that cheap power alone would not bring people to Niagara Falls; and, somewhat later, on August 8, 1889, there appeared in The Nation, a carefully written article tending to show that Mr. Evershed's tunnel would not be practicable for the production of power, nor commercially profitable. But strange to say, these objections have been fully answered through the demonstration of actual experience.

For three years the originators of the Niagara water-power project were engaged in convincing capitalists that it would be commercially profitable to undertake and complete the development of Mr. Evershed's plan, and the first step necessary to be taken was to demonstrate the advantages of the locality. It was shown that the capacity of the original tunnel, about 120,000 horse-power, would exceed the combined theoretical horse-power of Lawrence, Lowell, Holyoke, Turners Falls, Manchester, Windsor Locks, Bellows Falls and Cohoes, and would very largely exceed the actually developed power of all these places, and Augusta, Paterson and Minneapolis in addition. Considering the further right to construct an additional tunnel of 100,000 horse-power on the American side, and to develop at least 250,000 horse-power on the Canadian side, it was readily recognized how vastly this local development promised, in extent, to surpass the combined water-powers of almost any American State or section.

In the special volume upon water-power, constituting part of the United States census of 1880, it is stated that there were then in operation 55,404 water wheels, with an average of 22.12 horse-power each, making in the aggregate 1,225,379 horse-power. It thus appeared that the 450,000 horse-power available to the Niagara Falls Power Company represented more than a third of the power of all the wheels in the United States in 1880.

The question of the practical importance of the Niagara power being settled, Mr. Atkinson's next question arose as to the advantages of Niagara as a locality, and to this, answer was readily made by pointing out that there in the very heart of densest population, touched by nearly all the East and West trunk-lines, within a night's journey of Boston, New York, Philadelphia, Washington, Pittsburgh, Cincinnati, Cleveland, Chicago, Toronto and Montreal, was a natural port of the great lakes, sustained by a salubrious and fruitful



DEPTHS AND LEVELS OF THE GREAT LAKES.

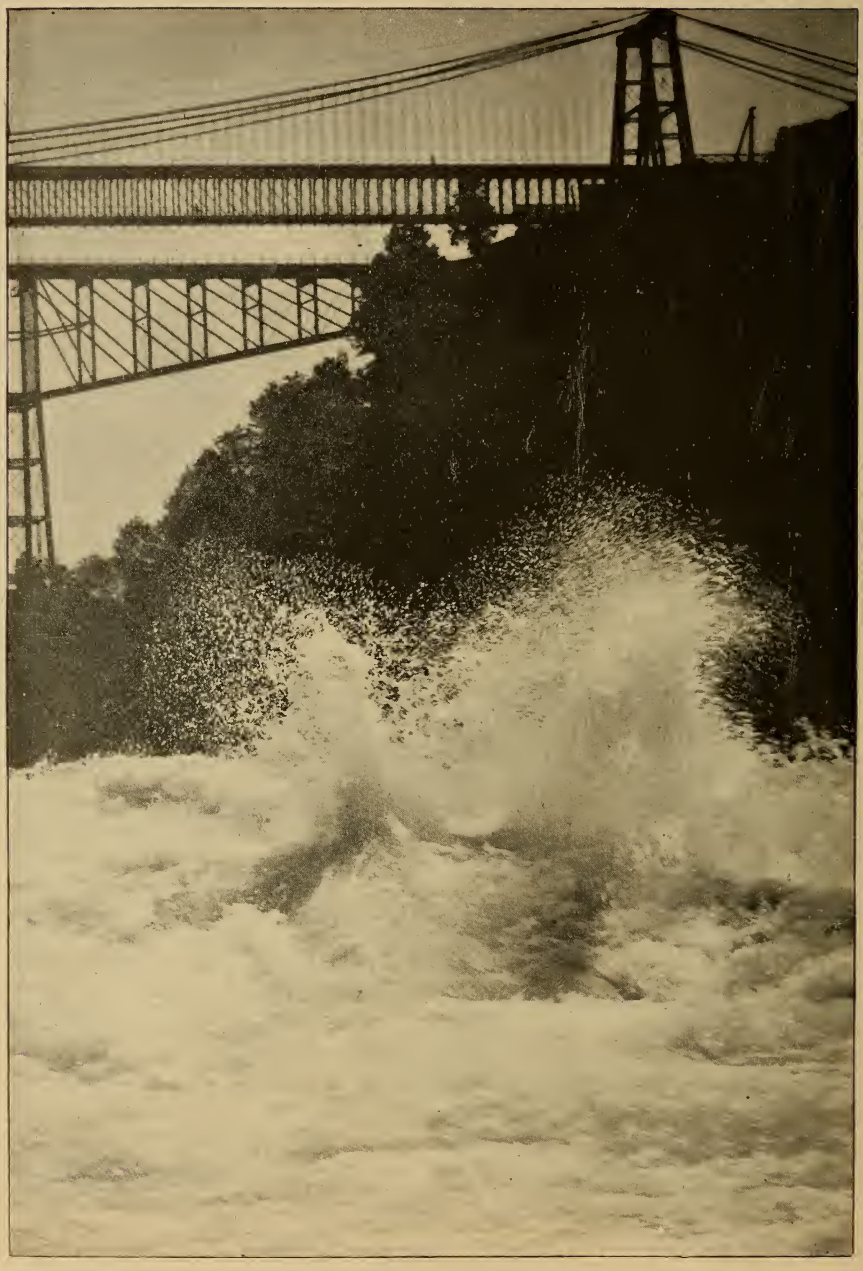
country, and protected by the orderly and established institutions and traditions of the most opulent and populous of the States of the Union. The existence of manufacturing establishments sufficient to exhaust all of the power then supplied by the hydraulic canal, and the subsequent applications for the new power, were and are the complete answer to the question whether, as a locality, Niagara would be attractive to users of power.

But the question still remained whether water-power could be used successfully in competition with steam, and there are few places in respect of which this question can be asked with more deadly effect; for, in the city of Buffalo, and indeed through the entire length of the district lying north of Pittsburgh, good steaming coal can be obtained at less than $1.50 a ton. With coal at this price, it would, at first, seem impracticable to establish any power plant capable of operating in competition with steam. But a careful examination has satisfied me, at least, that with coal furnished free at the furnace yard, it would still be economical for the manufacturer to employ water-power such as that at Niagara. When in England in 1890, I was told by an eminent gentleman that it was useless to discuss the profitable employment of water-power, for, as he said, "you can produce steam-power from coal at a cost of a farthing an hour," to which I answered:—"Very well, let us work out the problem! Coal, at a farthing an hour, would, in America, represent five cents for a day of ten hours, or 12 cents for a day of 24 hours, which is, for 300 days in the year, $15 for the short day and $36 for the long day for fuel only. At Niagara we will gladly furnish continuous 24-hour water-power for $15 a year, in any considerable quantity."

After careful consideration, the officers of the Niagara Falls Power Company reached the conclusions that 24-hour steam horse-power is not produced anywhere in the world for less than $24 a year; that in the production of the steam-power the cost of the fuel does not represent more than one-half of the total cost; that very few, if any, manufacturers have ever kept any separate account of the cost of their power, or have any actual knowledge of its cost; and that, aside from the cost of the power, many conveniences will come from the employment of power as it may be furnished from the Niagara river.

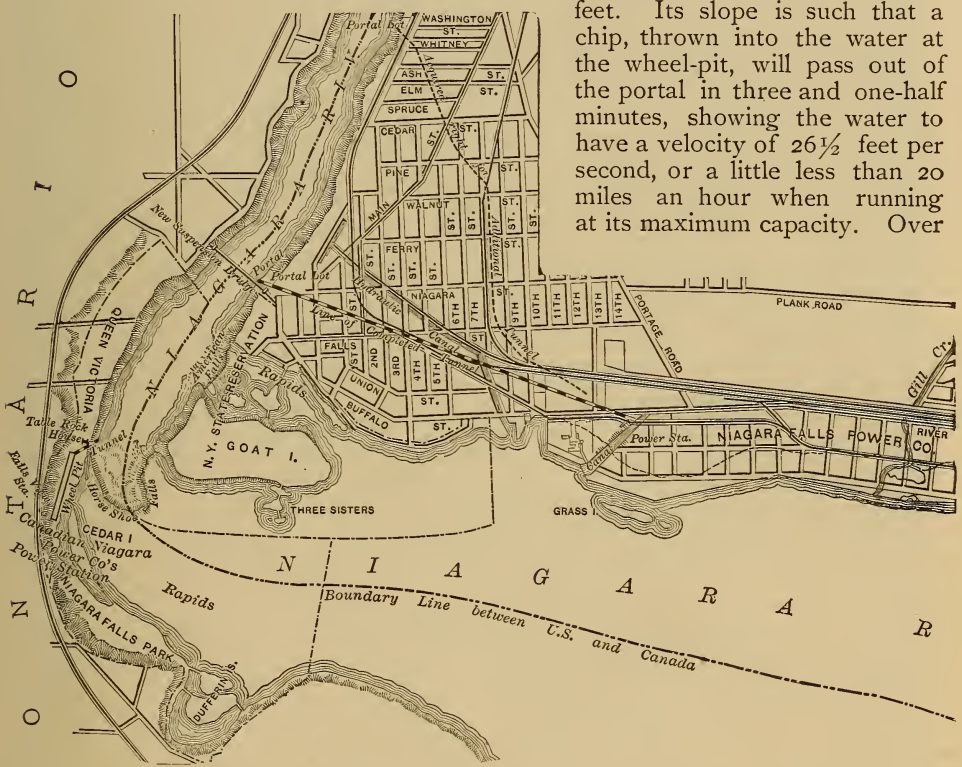
In view of all these considerations, in the year 1889 the present interests in the Niagara Falls power development were combined in a new corporation called the Cataract Construction Company, whose acceptance of the construction contract rested upon two propositions: First, that with proper organization and development the Niagara project would be valuable solely as a hydraulic installation; and, secondly, that it gave promise of becoming, within the very near future, vastly more valuable as a source of power for transmission. This company was the outgrowth of the very keen and appreciative interest in these propositions shown by the following gentlemen in the order named: William B. Rankine, Francis Lynde Stetson, J. Pierpont Morgan, Hamilton McK. Twombly, Edward A. Wickes, Morris K. Jesup, Darius Ogden Mills, Charles F. Clark, Edward D. Adams, Charles Lanier, A.J. Forbes-Leith, Walter Howe, John Crosby Brown, Frederick W. Whitridge, William K. Vanderbilt, George S. Bowdoin, Joseph Larocque, Charles A. Sweet of Buffalo and John Jacob Astor, most of whom have served as officers and directors of the construction company, giving freely of their time and experience to the conduct of the enterprise. Among all these names it may seem invidious to select any for special comment, but, after the early and continuing interest of Mr. Morgan and Mr. Mills, and the later accession of Mr. Astor, it was, as it continues to be, a matter of congratulation to the Cataract Construction Company that the origination, the development and the guidance of its affairs have, from the first, received the intelligent and continuous attention of its president, Mr. Edward D. Adams.

NEAR PROSPECT POINT AT NIGHT.



THE WHIRLPOOL RAPIDS BELOW THE FALLS.

In the order of development, of course, the first step was the adoption of a general plan. Dr. Coleman Sellers of Philadelphia having been retained as general consulting engineer, Mr. Clemens Herschel, formerly of Holyoke, was engaged as hydraulic engineer, and, in accordance with the views of these gentlemen, some slight modifications of



MAP OF NIAGARA FALLS AND VICINITY, SHOWING THE LOCATION OF THE GREAT TUNNEL.

wheel-pit in the power house at the side of the canal. This wheel-pit is 178 feet in depth, and is connected by a lateral tunnel with the main tunnel, serving the purpose of a tail-race, 7000 feet in length, with an average hydraulic slope of six feet in 1000, the tunnel having a maximum height of 21 feet and width of 18 feet 10 inches, its net section being 386 square feet. Its slope is such that a chip, thrown into the water at the wheel-pit, will pass out of the portal in three and one-half minutes, showing the water to have a velocity of 26½ feet per second, or a little less than 20 miles an hour when running at its maximum capacity. Over

Mr. Evershed's proposition were adopted. Generally speaking, the final plan comprises a surface canal, 250 feet in width at its mouth, on the margin of the Niagara river, a mile and a quarter above the Falls, extending inwardly 1700 feet, with an average depth of about 12 feet, serving water sufficient for the development of about 100,000 horse-power. The solid masonry walls of this canal are pierced at intervals with ten inlets, guarded by gates which permit the delivery of water to the 1000 men were engaged continuously for more than three years in the construction of this tunnel, which called for the removal of more than 300,000 tons of rock, and the use of more than 16,000,000 bricks for lining. The construction of the canal, and especially of the wheel-pit, 178 feet in length, with its surmounting power-house, were works of corresponding difficulty and importance.

After conference with various wheel-makers in the United States, it was

Prof. E. Mascart. Prof. W. C. Unwin. Lord Kelvin. Dr. Coleman Sellers. Col. Th. Turrettini.

THE INTERNATIONAL NIAGARA FALLS COMMISSION.

found that while American water-wheels of standard grades could be obtained of considerable excellence, yet, except in the case of the Pelton water-wheel, it was not easy to find wheels suitable for special requirements such as those of the Niagara Falls Power Company. The conclusion, therefore, to consider the employment of wheels of special design, which, in the nature of things, involved conference with foreign makers, to whom alone special design had become a matter of frequent occurrence, was reached upon the advice of Mr. Clemens Herschel, who was familiar with the use of the wheels at Holyoke which he had made a subject of careful study. The fact that Mr. Herschel himself advised recourse to foreign designers is a sufficient answer to some New England criticism that we did not adopt wheels such as have been used at Holyoke.

But, as soon as careful consideration was given to the subject of turbines, it also became quite apparent that it was desirable, contemporaneously and from the beginning, to take up and examine the question of power transmission, and it became equally apparent that by reason of the rapid advance in the art and science of the development and transmission of power, even the latest books upon this subject had become inadequate to our demand for information. In consequence of these conditions, Mr. Adams, while in Europe in the winter of 1890, happily conceived the idea of obtaining and perpetuating information as to the results and achievements of the engineers and manufacturers of the world not yet in the books, and, in conformity with this purpose, established in London, in June, 1890, an International Niagara Commission, with power to award $22,000 in prizes.

The commission consisted of Sir William Thomson (now Lord Kelvin) as chairman, with Dr. Coleman Sellers of Philadelphia, Lieut.-Col. Theodore Turrettini of Geneva, Switzerland, originator and engineer of the great water-power installation on the Rhone, and Prof. E. Mascart of the College of France, as members, and Prof. William Cawthorne Unwin, Dean of the Central Institute of the Guilds of the City of London, as secretary. Inquiries and examination concerning the best known existing methods of development and transmission in England, France, Switzerland and Italy, were made personally by the officers and engineers of the company, and competitive plans were received from twenty carefully selected engineers, designers, manufacturers and users of power in England and the Continent of Europe and also in America. All of these plans were submitted to the commission at London on or before January 1, 1891, and awards of prizes were made in respect of a number of the plans considered worthy by the commission.

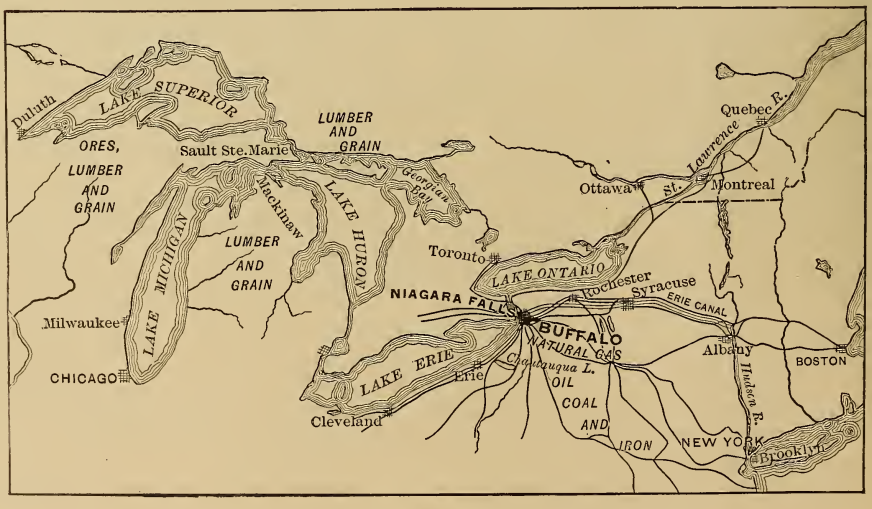
The first important result of this commission was the selection of Messrs. Faesch & Piccard of Geneva, as designers of the turbines, of which a careful description by Mr. Clemens Herschel is given elsewhere in this magazine. It is enough here to say that these wheels, calculated to yield 5000 horse-power each, are intended for a position in the wheel-pit, 140 feet below the surface, to which water is conducted by a tube or pen-stock leading from the service canal and discharging between the twin wheels, from which the water falls away into the side tunnel conducting it to the main tunnel and thus to the lower river. The power, of course, is developed through the drop in the wheel-pit, the tunnel serving the purpose only of a tail-race. Three of these wheels have actually been built after designs of Faesch & Piccard, by the I. P. Morris Company, of Philadelphia, and are now in place. They are about five feet in diameter. The pen-stock, 7½ feet in diameter, is made of steel, and the constant pressure of its column of water, discharging between the twin turbine wheels, serves to support the entire weight of all the revolving parts, namely, the weight of the wheels, the vertical shaft and the revolving parts of the generator driven by the wheel, to which reference will be hereafter made.

The mechanical problem to be solved in this case, viz.: how to get 5000

horse-power from the point of development at the wheels to the surface, 140 feet above, was considered to be much less difficult than that presented in the case of an Atlantic steamer, where the motive power of the 5000 horse-power engine is delivered by a horizontal shaft to the screw at the stern of the vessel, more than 140 feet away, the water-wheels at Niagara being our engine, the generator at the surface, our screw, and the connecting shaft (adopted in preference to belting or ropes), 140 feet in length, being vertical instead of horizontal. This shaft is of steel, ¾ inch thick, carefully rolled into tubes, 38 inches in diameter, without any riveted vertical seams; but at several intervals, where journals are needed to steady this vertical shaft on fixed collar bearings, it is solid and at those points measures 11 inches in diameter. While these turbines were made after foreign designs, the contract for building them was given to and was performed by the I. P. Morris Company, of Philadelphia, and, upon the observation of competent and disinterested experts, the Niagara Falls Power Company feels no hesitation in inviting general observation and criticism of this unusually difficult construction.

The question of the turbines having been thus disposed of, it became necessary to determine upon the mode of transmitting the power to be developed from them, and to this subject the careful attention of the officers and engineers of the company was addressed for more than three years, both in America and Europe. In 1890, four different methods of power transmission were seriously considered, viz., that by manilla or wire rope, that by hydraulic pipes, that by compressed air, and that by electricity. How rapid has been the progress of thought upon this subject within four years, may be realized when I say that in 1890, I was advised that power could be transmitted from Niagara to Buffalo, not by electricity, but only by compressed air, and that my adviser was Mr. George Westinghouse. But methods are clearer now than in 1890, and this largely is the result of the competition initiated by the International Niagara Commission.

Rapidly summarizing the results and incidents of a tour of inspection made by Mr. John Bogart, one of the engineers of the company, and myself, in 1890, I may observe that we saw five instances of transmission of power by manilla or wire ropes, viz., at Schaffhausen, Winterthur, Zurich and Fribourg, in Switzerland, and at Bellegrade, in France,



BUFFALO AND THE TERRITORY WHICH PAYS HER TRIBUTE.

NIAGARA FALLS IN WINTER.

all of these installations representing the effect of the original installation under Mr. Moser at Schaffhausen in 1867. Mr. Moser, a gentleman of great intelligence, was among the first to observe that the use of water-power had declined, and that the preference for steam-power had developed, because of the common inconvenience of the bringing of the factory to the source of the water-power, which inconvenience he thought to obviate by taking the power to the convenient site of the factory. This he did by the use of the wire ropes, sometimes to the distance of nearly a mile. But while this device served a useful purpose, it developed its own difficulties, especially in localities affected by cold or frost, under which conditions the wire rope frequently slipped on the wheels, an occurrence disastrous to spinning-mills, and which at Schaffhausen, is now leading to the substitution of electricity for the original wire transmission.

The second system of transmission visited by us was that upon a very large scale at Geneva, in Switzerland, instituted under the direction of Col. Turrettini, viz., hydraulic transmission of hydraulic power from the turbines, through pipes to different parts of the city, even for the purpose of operating dynamos for electric lighting. While this method of hydraulic transmission at Geneva did excellent work, it was already recognized in 1890 that it was not equal to electrical transmission of power, and in the duplication of the work now being made under the direction of Col. Turrettini, electricity is substituted as the means of transmission.

The third system of transmission, the pneumatic, had been developed to a very large extent in Paris, upon the system of Mr. Popp, under the observation of that most accomplished engineer, Prof. Riedler. Immense steam-power plants were established at Belleville, nearly seven miles

from the center of Paris, and at other points, and by the use of compressors over 7000 horse-power was distributed throughout Paris, operating more than 30,000 pneumatic clocks in the hotels and residences, supplying refrigeration for the stores for meats in the Bourse de Commerce, and also an installation for electric lighting near the Madeleine. We also observed the Sturgeon & Lupton system of pneumatic transmission in Birmingham, and later the important example of such transmission from the Menominee river, seven miles away, to the Chapin iron mine, at Iron Mountain, in Michigan. This was the system which, in 1890, Mr. Westinghouse thought we were likely to adopt. But, in view of the great loss of power, the Popp system yielding only 38 per cent. in efficiency, and the Birmingham system yielding only 52 per cent., upon comparatively short distances, it did not seem wise to the Niagara Falls Power Company to adopt this system, useful and valuable as it is in many particulars; but it is gratifying to be able to state that in the International Niagara competition a prize for a project for distributing power pneumatically, was awarded to the Norwalk Iron Works Company, of Connecticut.

A very interesting debate as to the comparative merits of electricity and compressed air was conducted in September, 1890, in my presence, between Prof. Riedler in behalf of compressed air, and Mr. Ferranti in behalf of electricity. Mr. Ferranti said that the electrical system was especially adapted to long transmission of great volumes, inasmuch as the loss increased only inversely as the square of the increase of volume; that is, if a loss of 50 per cent. were to be assumed for transmission of 5000 volts, that loss would increase only one-half upon doubling the volume—in other words, a transmission of 5000 volts with a loss of 50 per cent. might be increased to 10,000 volts with a loss of only 25 cent. of the increase, or 37½ per cent. of the aggregate amount, or, stated concretely, though 5000 volts might yield only 2500 volts, 10,000 would yield 6250 volts of the power developed. Prof. Riedler was greatly puzzled by Mr. Ferranti's positive statement, and said that, if well founded, the loss in the case of electricity differed from that of every other known force, to which Mr. Ferranti replied that this undoubtedly was so, and that the differences were altogether to the advantage of its employment upon a great scale for such a service as this. Prof. Riedler concluded by saying to Mr. Ferranti that if his statements were well founded, there could be no question but that electricity must prevail over compressed air. This was in 1890, and all subsequent experience has tended to confirm the statements of Mr. Ferranti, Mr. Nikola Tesla having quite recently stated to me that if the company would put 100,000 horse-power upon a wire, he would deliver it at commercial profit in the city of New York.

The fourth method of power transmission was that by electricity, which we found in actual operation in three places, all in France—Oyannax, Doméne and Paris, besides the short transmission within the buildings of the Oerlikon Company, near Zurich, in Switzerland. Other examples, contemporaneously or subsequently developed, might be referred to, but these are they upon which, in 1890, the Niagara Company founded its preference for electrical transmission. At Oyannax, on the Jura Mountains, in the Department of Ain, there was a variety of small interests, the principal one being the manufacture of silk, the smaller ones being the manufacture of tortoise-shell combs and other lighter articles, in which not more than two or three horse-powers were employed for the running of small saws and polishers. The power for these various simple industries was derived from turbines in the Ain river at Charminet, distant in a direct line about five miles from the use of the power. At Doméne, opposite the Grande Chartreuse, in the Dauphiny Alps, the power for a paper mill was drawn from a glacier in the mountain, four miles away, almost straight up in the sky, and in winter actually inaccessible, so that for three months the only communication between

ICE BRIDGE UNDER THE FALLS.

THE HORSESHOE FALLS FROM GOAT ISLAND.

the mill and its source of power was by telephone. Here, sleety storms prevail, and snow and frost to an extent equal to that conceivable at Niagara, and yet the results were so satisfactory that Mr. Chevrant, the owner of the mill, said that his power did not cost him over 50 francs a year.

But passing from these examples of 1890, through the larger experience by which power was transmitted 16 miles from Tivoli to Rome, and for a long distance at Portland, Oregon, and also at Telluride, in Colorado, in all which places power, generated at a water-power station, is transmitted with bare copper wires on poles for ten miles and more with commercial success, the Niagara Company, in December, 1891, under the advice of Prof. Rowland, of Johns Hopkins University, Prof. George Forbes, of London, and Prof. Sellers, of Philadelphia, invited competitive plans and estimates for the development of its electrical power and of its transmission both locally and at Buffalo. As the result of this advice and this competition, the company adopted a two-phase alternating generator of 5000 horse-power, developing about 2000 volts with a frequency of 25, as the best practicable unit and method for the development of electricity for power purposes. It is distinctly recognized that a higher frequency in the present state of the art is desirable for arc lighting, and is necessary for incandescent lighting; but having regard to the special purpose, and conditions of this company, it was decided to adopt that method and system which is, on the whole, best fitted for a power company as distinguished from a light company. It is only proper to say that in the adoption of the alternating system, as opposed to the continuous system, in the adoption of the two-phase, as distinguished from the three-phase, and in the adoption of the frequency of 25, the company was diversely advised and criticised, and the result finally reached was that which, upon the whole, under existing, present conditions, seemed best.

ANOTHER VIEW NEAR PROSPECT POINT.

The form of dynamo employed is that devised by the company's electrical engineer, Prof. George Forbes, of London, resembling a mushroom or umbrella, in which the stalk or handle is the shaft of the turbine, and the cap is the revolving part of the generator, serving the purpose also of a fly-wheel for the turbine, this special advantage having resulted from Prof. Forbes' happy idea of a dynamo in which the field magnets should revolve instead of the armature. A contract for three such dynamos, of 5000 horse-power each, was made with, and was performed by,

the Westinghouse Company at Pittsburgh. The first users of the power developed from these dynamos were the Pittsburgh Reduction Works, manufacturers of aluminum, having an establishment also at Pittsburgh. Their works at Niagara are upon the lands of the company, 2500 feet distant from the power-house, which is reached by an underground conduit for electrical transmission. After a competition for a design and construction of works suitable for the transmission of electrical power to this establishment, and for converting the alternating into a continuous current, a contract was made with, and carried out by, the General Electric Company, of Schenectady, N.Y. At the same time, both the Westinghouse Company and the General Electric Company, in competition, have submited plans for the transmission of electric power to Buffalo, and, upon the adoption of the successful plan, the Niagara Falls Power Company is prepared to proceed with the construction and operation of a plant for transmission of electricity to that important city on Lake Erie.

How much farther such power may be transmitted at a commercial profit remains to be seen. Messrs. Houston & Kennelly, well known electrical engineers, independently reached the conclusion that even so far away as Albany (a distance of 330 miles) electrical power, with a steady load of 24 hours per day, can be delivered at $22.14 per kilowatt, which is cheaper than it can be produced by triple-expansion steam engines, though the cost would be proportionately greater for 10-hour power. Though these figures are gratifying, they are not those upon which the Niagara Falls Power Company is resting for the success of its undertaking. Whether or not electrical power can be furnished 330 miles away at less than $24 a day for 24-hour horse-power, it can, within much nearer distances, be furnished at such prices as to leave very little surplus power for distribution at such remote points ; and, on the other hand, if it be practicable to transmit power at a commercial profit in these moderate quantities to Albany, the courage of the practical man will not halt there, but, inclined to follow the daring promise of Nikola Tesla, would be disposed to place 100,000 horse-power on a wire and send it 450 miles in one direction to New York, the Metropolis of the East, and 500 miles in the other direction to Chicago, the Metropolis of the West, and serve the purposes and supply the wants of these greatest urban communities.

Conscious of the difficulties of transferring, at once, large industries to a new site, even as attractive as it has made Niagara, with its new industrial village of Echota, designed by Stanford White, and the new Terminal Railroad owned by kindred corporations, the Power Company, notwithstanding encouragement from such home tenants as the great Paper Company and the Aluminium and the Carborundum works, has definitely determined to furnish its power to distant consumers, even at the risk of work which, in some measure, must be experimental, though not in so large a degree as many may suppose. Tivoli, Turin, Telluride, Genoa, Williamette, San Bernardino, all tell that commercial success lies back of the brilliant experiment, in 1891, of Lauffen and Frankfort, 109 miles apart.

Buffalo, being reached, is only on the way to points beyond. How far beyond, it is not necessary now to determine ; but having once set in motion these mighty wheels, we may at least imagine and admire a bow of brilliant promise,—an arc of electrical energy stretching from the Metropolis of the Atlantic to the Metropolis of Lake Michigan, whose waters, swelling the mighty flood that stirs Niagara, may then be called upon to drive

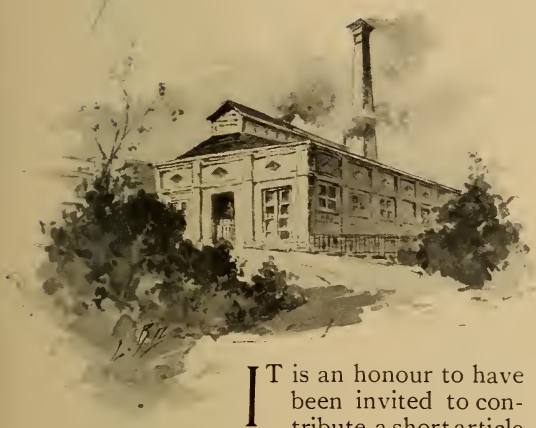
"The roaring loom of time itself."

W. C. Unwin

PROF. WM. CAWTHORNE UNWIN is one of the best known engineers, authors and teachers of engineering science in England, as well as in America. He was a member of the International Niagara Falls Commission.

MECHANICAL ENERGY AND INDUSTRIAL PROGRESS.

By W. Cawthorne Unwin, F. R. S.



IT is an honour to have been invited to contribute a short article to a number of CASSIER'S MAGAZINE, devoted to a description of the work at Niagara, and it is pleasant to be so associated with those who have had the task of planning the arrangements, superintending the works and designing the machinery of that grand installation. Writing, however, on the European side of the Atlantic, it will be wisest,—not to say most modest,—to avoid details and to deal, in preference, with some general consideration bearing on the question of utilizing and distributing power.

In all producing industries, there are operations requiring greater, and operations requiring less, intelligence; operations requiring great manual skill, and others requiring little manual skill. The sub-division of labour which has arisen in modern industries has for its object to economize the intelligence and skill and other special faculties of the workers. A factory should be so arranged that manufacture is carried on by the most advantageous number of processes, each worker doing what he is best fitted to do, and the number of workers in each class being proportioned to the requirement of the process allotted to it. The sub-division of manufacture in this way greatly facilitates the introduction of machinery, and with the use of machinery comes the need for motive power, more constant and tireless than muscular effort. Comparing the last hundred years with any previous period, their most obvious characteristic is the enormous extension of the use of mechanical energy derived from natural sources.

At first, factories were placed near waterfalls from which alone, at that time, mechanical energy could be easily obtained in sufficient quantity. Then, about the year 1790, steam power began to replace water power. For a time, the factories were aggregated near coal fields. To some extent this is still the case, though facilities of transport, due again to the use of natural supplies of energy, permit manufactures to spread more widely. In any case, the location and the growth of manufactures have been largely determined by facilities for obtaining cheaply large quantities of power.

In 1832, Charles Babbage, the inventor of the well-known calculating engine, published an interesting work on "The Economy of Machinery and Manufactures." It deals with the guiding principles underlying modern methods of manufacture, then already so far developed as to be recognized as constituting a new system. It is curious that Babbage says little about the production of power or its cost, though, clearly, the use of cheap steam power was the principal factor in the industrial change which he discusses. Towards the end of the book, however, he does mention that the application of the steam engine had added millions to the population of Great Britain.* Then

*Mr. Thomas Hawksley often said that the population of Great Britain had trebled in his lifetime.

THE HORSE SHOE FALLS AT NIAGARA.

he points out that the source of steam power,—the fuel,—is limited in quantity, and that a time may come when the coal mines will be exhausted. He mentions the tides as an inexhaustible source of energy, if means could be found for utilizing tidal action.

Finally, he indulges in a curious speculation. He points out that hot springs, which have been observed to flow for centuries, unchanged in temperature, bring to the surface a practically unlimited supply of heat. "In Iceland," he says, "the sources of heat are plentiful and their proximity to large masses of ice almost points out

the future destiny of that island. The ice of its glaciers may enable its inhabitants to liquefy the gases with the least expenditure of mechanical force, and the heat of its volcanoes may supply the power necessary for their condensation. Thus, in a future age, power may become the staple commodity of the Icelanders."

Manufacturers have not yet been driven to obtain power by purchasing liquefied oxygen in Iceland. The coal fields are not yet exhausted. But the pressure on trade of the cost of the energy required is undoubtedly felt. This may be inferred from the ceaseless efforts to reduce the consumption of steam in engines, and to improve the efficiency of boilers. There are obvious causes for this. As trade competition becomes more severe, every item of expenditure in carrying on work is scrutinized, and out of many small economies a material advantage is reaped. Even if in some industries the annual cost of power is a small fraction of the total expenditure, any saving on it is a clear addition to profits.

In many industries there is an increasing consumption of power, processes being multiplied to secure greater perfection of product, and then the cost of power is an increasing tax. Lastly, there are new electrical and chemico-electric industries in which the amount of power used is very large, and its cost is not a small fraction of the expenditure. In electrical industries, mechanical energy is virtually the raw material of the manufacture, and its cost is not a subordinate, but a principal, factor in the cost of production.

In an article in *Engineering*, several years ago, Dr. Coleman Sellers quoted some estimates of the amount of power required in different industries. These

THE FALLS NEAR PROSPECT POINT.

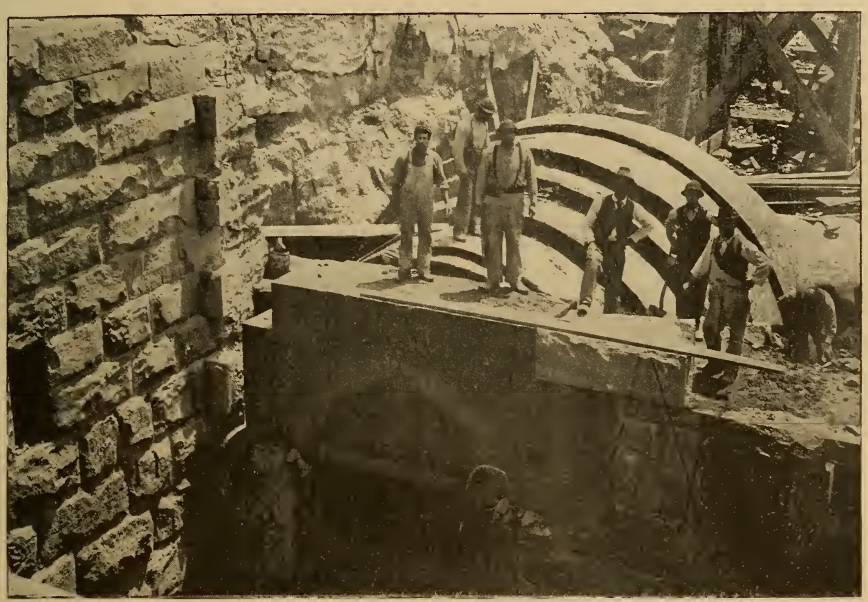
BEGINNING THE POWER CANAL AT NIAGARA.

are given conveniently in horse-power per artizan or worker employed. Taking the cost of one horse-power year at about £12 or $60, which is a moderate, average estimate, the annual expenditure per worker can be calculated in supplying the mechanical energy necessary to make his labour effective.

Industry.	Horse-power for each hand employed.	Cost per annum per hand employed. £ s.	$
Flour and grist mills	13.20	158 8	(792)
Lumber sawing.....	5.56	66 12	(333)
Cotton.....	1.49	17 16	(89)
Paper.....	5.07	60 16	(304)
Woollen goods.....	1.23	14 16	(74)
Iron and steel.....	2.82	33 16	(169)
Agric'ral implem'ts.	1.13	13 12	(68)
Worsted goods.....	0.87	10 8	(52)

The figures in the last column are the annual charges, additional to his wages, for each worker for the mechanical energy he uses. Obviously, these charges are not amongst the negligably small items of a manufacturer's expenses.

In the case of electric lighting stations, the proportionate cost of power is enormously greater. From figures known to be reliable, it appears that in stations in England the cost of fuel alone per electrical unit sold, apart from interest on cost of boilers and engines and wages and maintenance, is seldom less than one penny, and is, in some cases, double this. But the ordinary selling price of electricity is 6 pence per unit, so that the fuel cost alone absorbs one-sixth of the gross income of the works, and in some cases one-third.



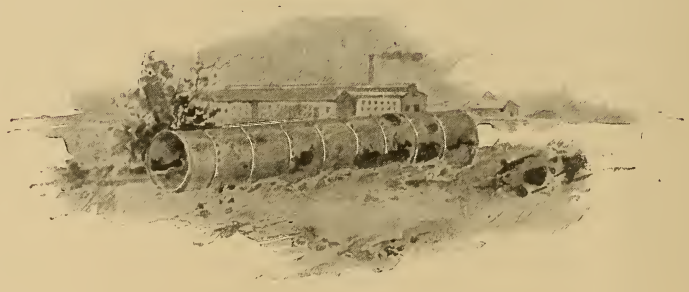
IN THE NIAGARA WHEEL-PIT DURING CONSTRUCTION.

Up to the present time by far the largest part of the mechanical energy used in the world has been derived from the combustion of fuel. But in the best steam engines the limit of possible economy has been nearly reached. A good deal may be effected, no doubt, by replacing bad engines and boilers by good engines and boilers, but there is little reason to hope that any steam machinery of the future will work with materially greater economy than the best at present in use. Nor is there much hope of considerable economy from the improvement of other heat

engines. Short of going to Iceland, there is only one widely distributed, easily utilizable source of mechanical energy, and that is water power.

Under favourable conditions, and utilized on a large scale, the cost of water power near the waterfall may be one-tenth or one-twentieth of the cost of steam power. The difference is so great that even when considerable cost is incurred in transmitting the power from the waterfall to localities where power is required, there may be a margin of economy in using water power. No doubt, in many cases, especially where very great, permanent structures had to be erected to render falls of considerable height available, water power has proved as expensive as steam power.

Modern facilities of transmission and distribution have greatly altered the conditions of the problem, and engineers in several countries have come to realize the value of the waste energy of the streams. No one can now travel in Switzerland or southern Norway without perceiving that a new impetus has been given to industry by the development of large water power plants. In Norway a new industry,—the paper pulp trade,—has, in a few years, become extremely important, and the manufacture is carried on entirely by cheap water power, derived from considerable falls on the glacier-fed streams. In utilizing a great waterfall and distributing widely cheap mechanical power, the capitalists and engineers at Niagara are helping to solve one of the most interesting and important problems of the present time.

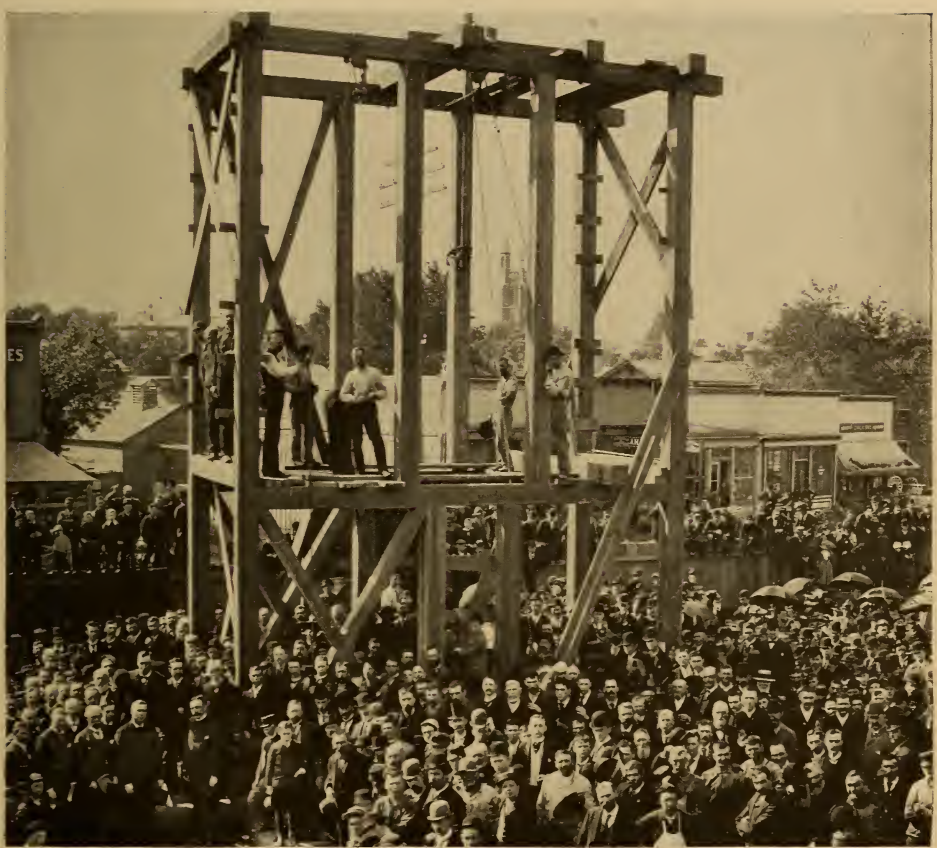


Albert H. Porter

ALBERT HOWELL PORTER was the resident engineer for the Cataract Construction Co. until the completion of the tunnel, and the preliminary work was done under his immediate supervision.

SOME DETAILS OF THE NIAGARA TUNNEL.

By Albert H. Porter, M. Am. Soc. C. E.

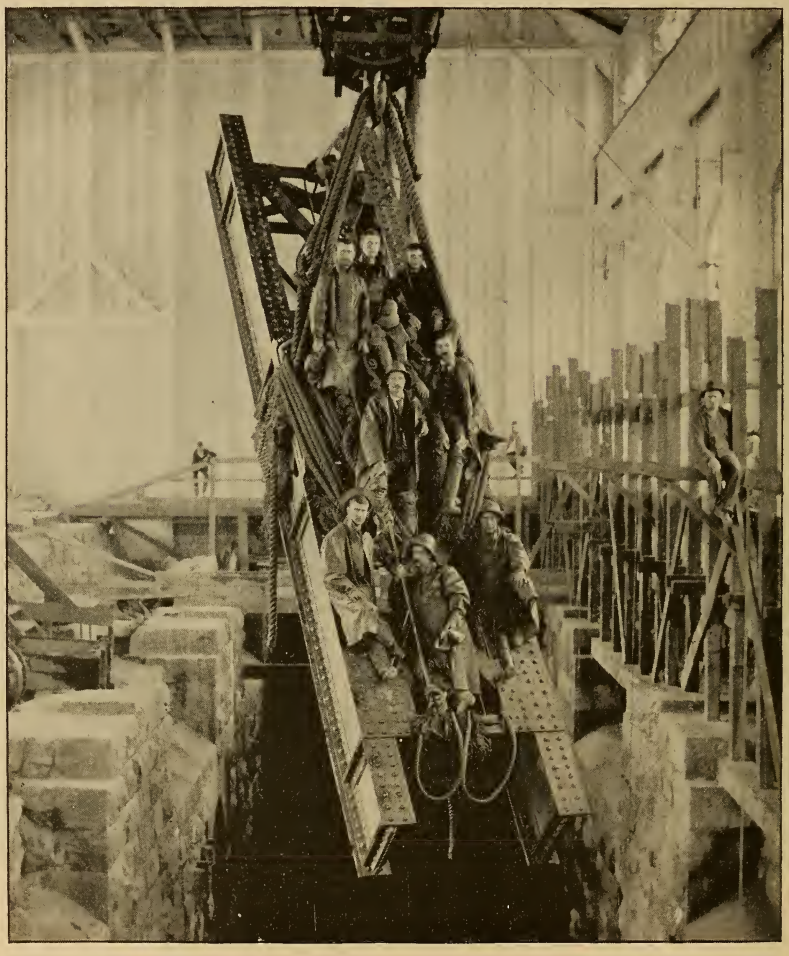


OPENING CEREMONIES AT THE BEGINNING OF THE FIRST SHAFT FOR THE NIAGARA TUNNEL.

IN the latter part of March, 1890,—a short while ago it seems when one sees the progress made toward the completion of the greatest water power project and enterprise of our time, which has changed Niagara Falls, then only a village, into a thriving city with the eyes of the world upon her,—surveys were commenced of the lands of the Niagara Falls Power Company and Cataract Construction Company, and the location of the great tunnel from these lands, under the village to the river below the Falls, was begun. A right of way had been acquired previous to this, surveys of which were started immediately to see what additional grants would be necessary to locate the tunnel in a straight line, which was desirous for constructional and hydraulic reasons.

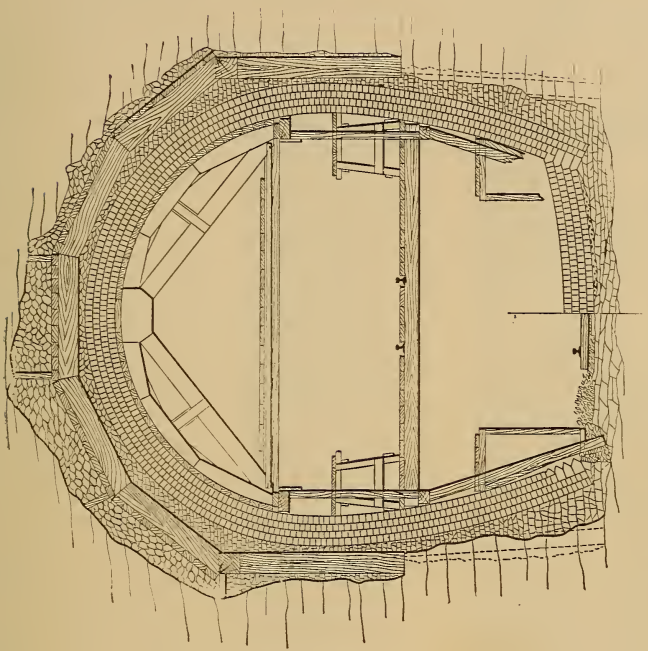
This right of way was largely covered

with buildings, and in order to more readily and accurately perfect the surface alignment, a tower was erected just east of the New York Central & Hudson River Railroad depot. The tower was a double one, over fifty feet in height, with three legs to each tower, the inside one being the tripod for the alignment instrument, while the outside one, which was entirely clear of the tripod, in order that there should be no jarring or vibration, had a platform for the engineers to stand on in sighting the instrument. From the top of the tower all buildings could be cleared and a point set in Canada, from which points were thrown back across the gorge to the tunnel portal. Points were also set east of the tower for the shafts and along the line of tunnel. The profile accompanying shows the location of the tower, its use and advantage, and will readily explain the method of alignment.

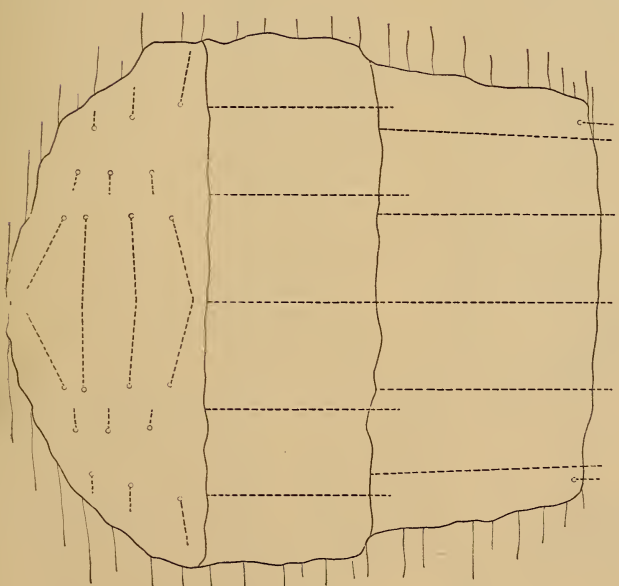


LOWERING A GIRDER INTO THE WHEEL-PIT.

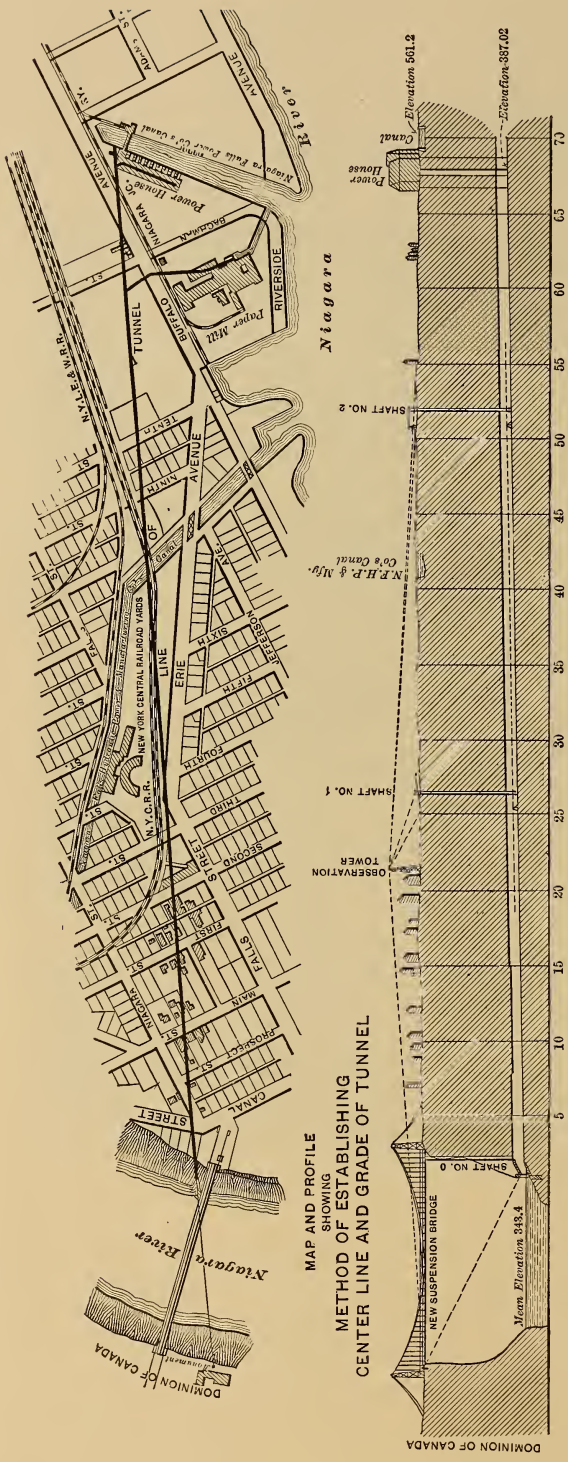
The work of constructing the tunnel was prosecuted from two shafts and the portal in the lower river. There was also a shaft at the portal at the top of the sloping bank to enable a straight lift to the top of the bluff. Shaft No. 1



CROSS SECTION OF TUNNEL, SHOWING METHOD OF LINING.



CROSS SECTION OF TUNNEL, SHOWING POSITION OF DRILL HOLES.



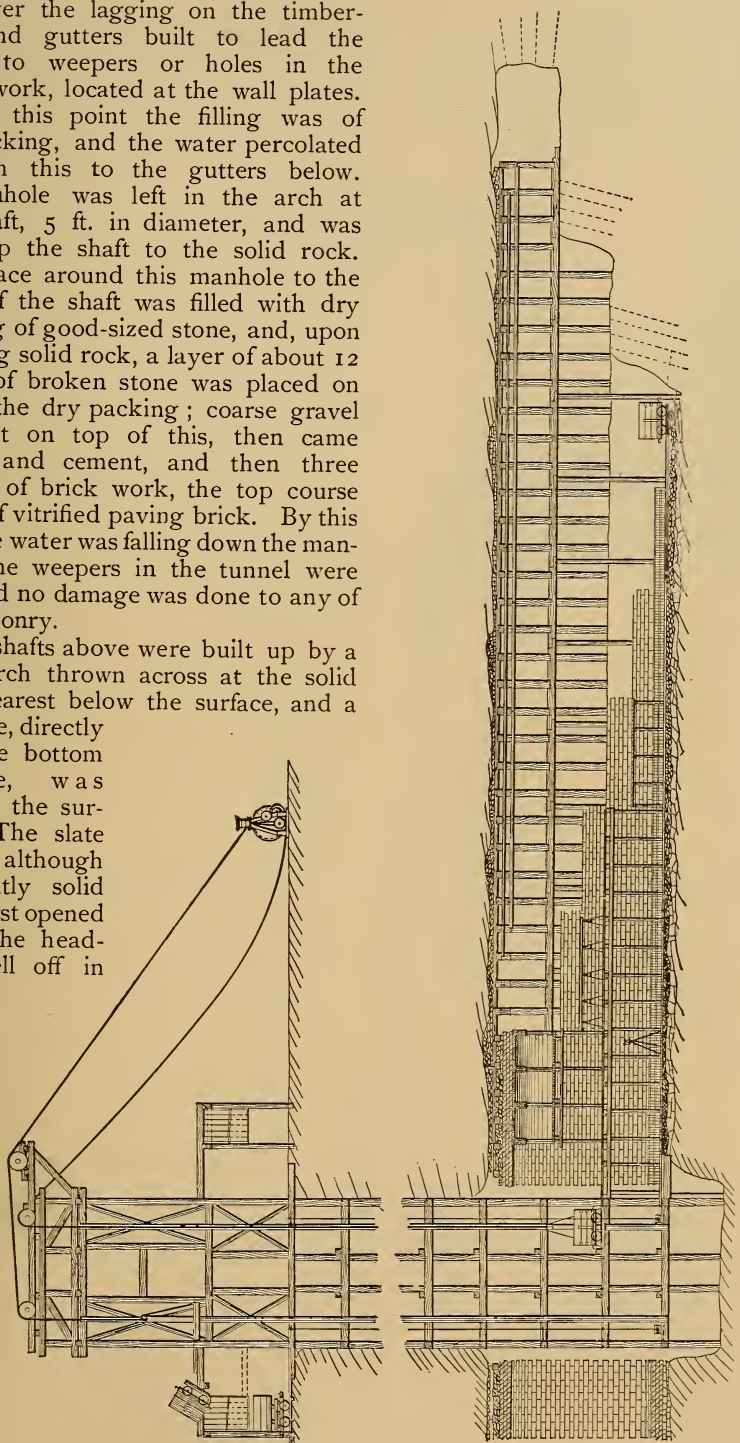
was located 2600 feet, and shaft No. 2, 5200 feet from the portal. Points for diamond drill borings were located along the line of the tunnel, and borings were made at several places. From the results of these borings the profile showing the rock stratifaction was made. From the rock cores taken out by these borings, it was thought that an unlined tunnel could be driven, but after sinking the shafts and driving the headings a short distance, the rock was found to be of such a character that, upon consultation, it was deemed necessary to line the tunnel throughout, not only to make a safe and practical construction, but to have a more perfect tailrace.

The upper stratum, or the Niagara lime-stone, is a hard rock, but is full of seams, through which the water comes in great quantities, and in sinking the shafts this water caused much trouble and greatly increased the difficulties of construction. In order to intercept the water from falling to the bottom, the plan shown in one of the appended illustrations was devised, by which gutters were cut and built around the shafts leading to basins or sumps in the sides of the shafts where pumps were placed and the water was forced to the surface. In shaft No. 1 fully eight hundred gallons of water a minute were pumped.

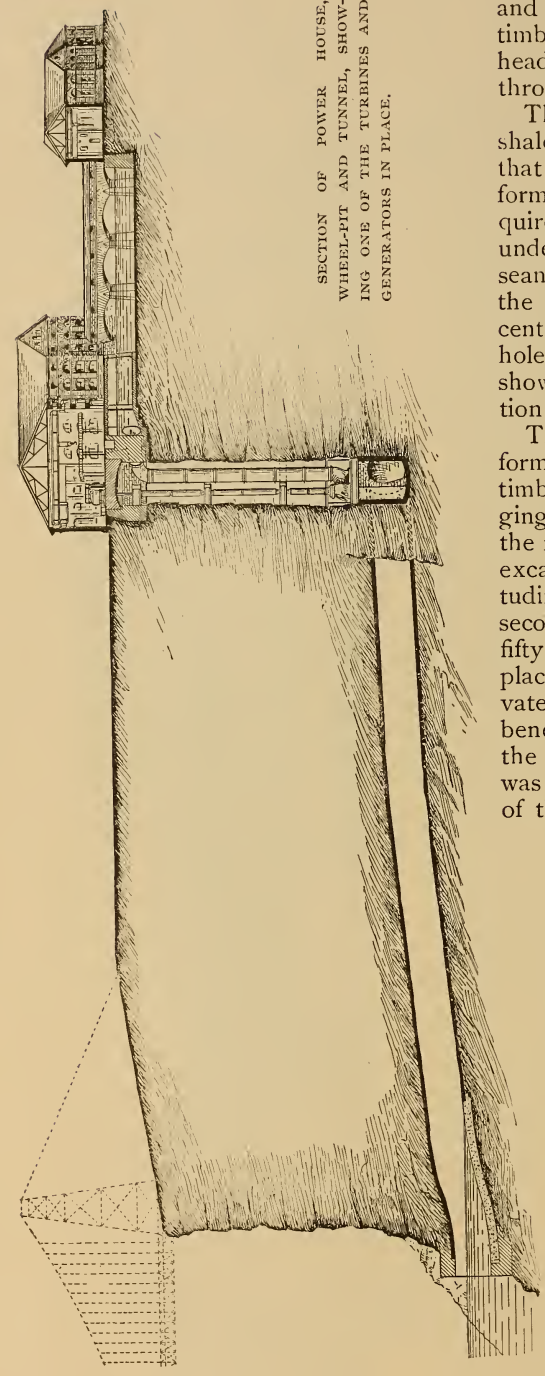
When the brick work of the tunnel was completed and the working shafts were being closed up, the water again caused serious obstacles to the construction of the brick work and masonry. To obviate this, tar paper was

put over the lagging on the timbering, and gutters built to lead the water to weepers or holes in the brick work, located at the wall plates. Above this point the filling was of dry packing, and the water percolated through this to the gutters below. A manhole was left in the arch at the shaft, 5 ft. in diameter, and was built up the shaft to the solid rock. The space around this manhole to the sides of the shaft was filled with dry packing of good-sized stone, and, upon reaching solid rock, a layer of about 12 inches of broken stone was placed on top of the dry packing; coarse gravel was put on top of this, then came gravel and cement, and then three courses of brick work, the top course being of vitrified paving brick. By this time the water was falling down the manhole, the weepers in the tunnel were dry, and no damage was done to any of the masonry.

The shafts above were built up by a brick arch thrown across at the solid rock nearest below the surface, and a manhole, directly over the bottom manhole, was built to the surface. The slate rock, although apparently solid when first opened up in the headings, fell off in



LONGITUDINAL SECTION, SHOWING METHOD EMPLOYED IN SINKING SHAFT, AND TIMBERING, BRICK-LINING AND DRIVING THE MAIN TUNNEL.



SECTION OF POWER HOUSE, WHEEL-PIT AND TUNNEL, SHOWING ONE OF THE TURBINES AND GENERATORS IN PLACE.

large slabs when exposed to the air, and necessitated not only temporary timbering and props in the advance heading, but permanent timbering throughout.

The layer of limestone under the shale was a firm strong rock, and in that portion of the tunnel where it formed the roof, no timbering was required. The sand stone and sand shale under the limestone were full of clay seams. The system of blasting used in the heading was the American, or centre cut method, the location of drill holes for the heading and benches being shown on the accompanying cross section and profile.

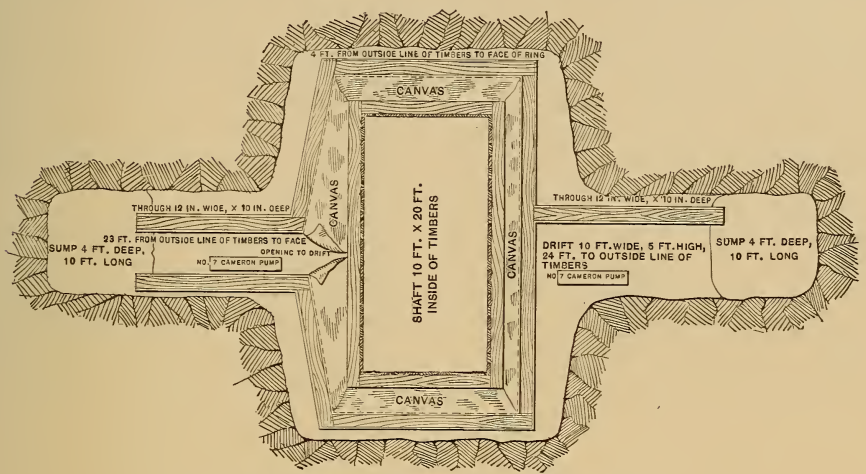
The permanent timber arch was formed of five blocks of 12 x 12-inch timbers, covered with three-inch lagging, packed over with dry stone to the rock roof. The first heading was excavated to the bottom of the longitudinal timber or wall plates. The second bench followed within about fifty feet of the heading, posts being placed under the wall plates, as excavated. The heading and first or upper bench were carred along together until the headings met. The lower bench was excavated a short distance ahead of the brick lining. In some cases, on account of the poor rock, it was found necessary to place long posts to the bottom of this bench to support the wall plates.

The best progress made in any heading during the construction of the tunnel was 94 feet in one week. The best progress for the five headings was 331 feet in one week, an average of over 66 feet to each heading, and the same week 321 feet of the first bench were taken out and the timbering was carried along. The brick work was built in the different sections, as shown on the profile and plan.

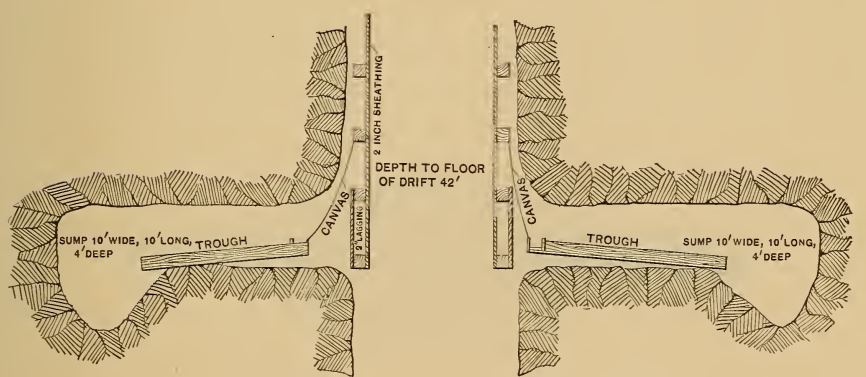
The brick side-walls were built first, a specially formed brick being used where the invert or bottom joined on. The invert was the last brick work to be laid in the tunnel. For setting these

side-walls a templet or form was set on correct grade and line. This was made, as shown in the section, with notches cut for the special brick and saw cuts made for each course of brick. Above these the centres were set which were

On the accuracy of alignment and grade depended the meeting and outcome of all the different steps described above. The alignment in the tunnel was produced from two small steel piano wires suspended from the surface


4 FT. FROM OUTSIDE LINE OF TIMBERS TO FACE OF RING
CANVAS
CANVAS
SHAFT 10 FT. X 20 FT. INSIDE OF TIMBERS
CANVAS
CANVAS
THROUGH 12 IN. WIDE, X 10 IN. DEEP
23 FT. FROM OUTSIDE LINE OF TIMBERS TO FACE OPENING TO DRIFT
SUMP 4 FT. DEEP, 10 FT. LONG
NO. 7 CAMERON PUMP
THROUGH 12 IN. WIDE, X 10 IN. DEEP
DRIFT 10 FT. WIDE, 5 FT. HIGH, 24 FT. TO OUTSIDE LINE OF TIMBERS
NO. 7 CAMERON PUMP
SUMP 4 FT. DEEP, 10 FT. LONG

PLAN SHOWING ARRANGEMENT OF TROUGH AND CANVAS.



SECTION THROUGH CENTRE OF DRIFTS.

PLAN ADOPTED FOR HANDLING WATER AT SHAFT NO. 2.

especially adapted to the arrangement of scaffolding and the method of handling material used, which are shown on the cross and longitudinal sections. The spaces between the brick work and the rock and around the posts were all filled with rubble masonry up to the haunch of the arch. Above this and over the brick arch dry packing was used.

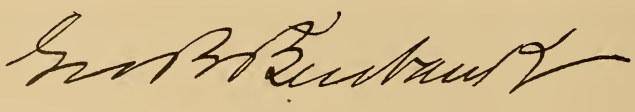
with 30 lb. flanged plumb bobs, hanging in buckets filled with oil. These wires were on movable screws on the surface, and were kept on the true line with a transit instrument about 30 or 40 feet from the shaft. The distance between the wires was about 17 feet. From these wires at the bottom a transit instrument was sighted and worked on to the true line and points

set in the tunnel. This was repeated three times, or until the result proved satisfactory.

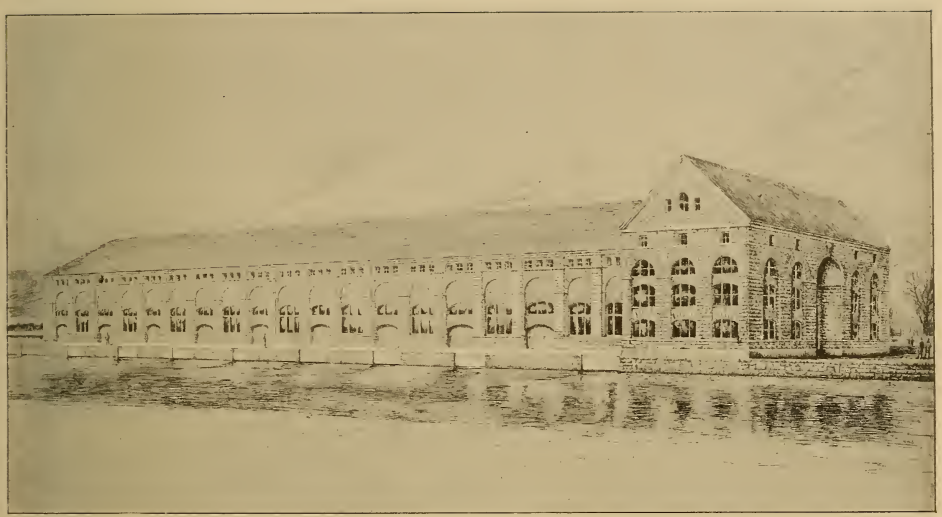
The elevations were established at the bottom of the shafts by means of a long accurately tested steel tape, kept on a known elevation on the surface by means of a level instrument, and read at the bottom by another level from which the elevations were established on bench marks of iron bolts, secured in the rock. This was also done three times, or until a satisfactory result was obtained. The result of the alignment and grade of the tunnel was most satisfactory, as there was no deviation or error in all the construction, and no work had to be changed or torn out. The clearance allowed between the timbering and brick work was only 4 inches, the smallest in any tunnel.

The tunnel shafts were started late in September, 1890. The tunnel for a length of 6700 feet was entirely completed in January, 1893, and the final estimate for the contract of the main tunnel was made in March, 1893. The material excavated from the tunnel was used to fill up the lands under water acquired by the company, a small railroad being built from shafts Nos. 1 and 2 for that purpose. To-day the greater part of the plant of the Niagara Falls Paper Mill stands on land which was then mostly all under the water of the Niagara River.

During the summer and fall of 1890, contour surveys of the lands and river adjoining them were made, and from these the best entrances from the river, location of the canal, wheel-pits, etc., were determined upon by the engineers.



GEORGE BARKER BURBANK was the resident consulting engineer of the Cataract Construction Co. during the period covering probably the most important part of the work, and later was chief engineer. His article here embraces the first official statement ever made regarding it.



THE NIAGARA FALLS POWER COMPANY'S STATION.

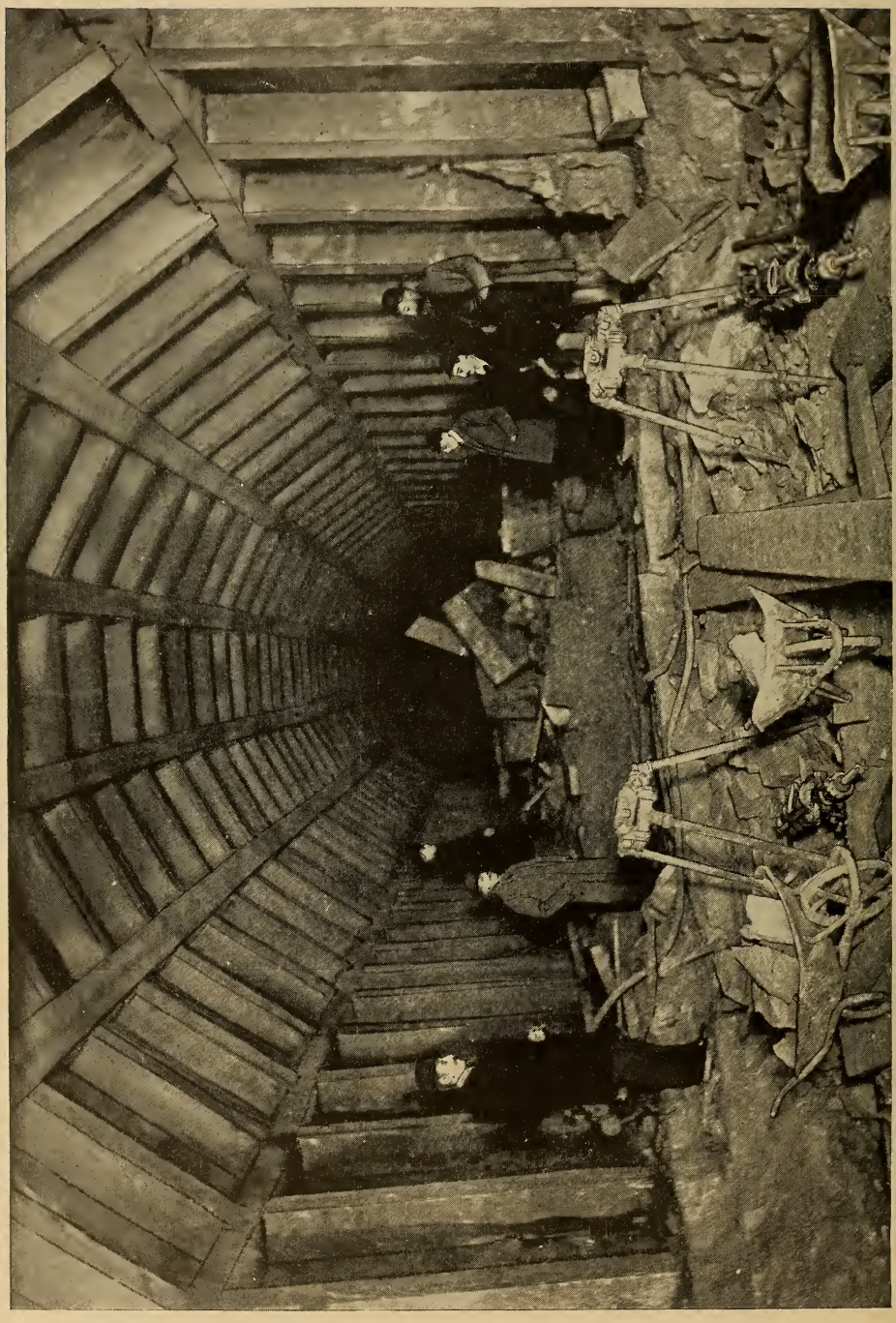
THE CONSTRUCTION OF THE NIAGARA TUNNEL, WHEEL-PIT AND CANAL.

By George B. Burbank, Mem. Am. Soc. C. E.

IN the latter part of May, 1891, the writer was called upon by the Cataract Construction Company to examine and report as to the necessity of lining the main tunnel of the Niagara Falls Power Company at Niagara Falls. At that time, under the direction of Resident Engineer Albert H. Porter, the shafts had been sunk to the tunnel level, and headings had been driven for 50 to 75 feet from the shafts.

In these headings the material to be encountered while driving the tunnel was fully developed. An argillaceous shale was found which, upon exposure to the air, crumbled away, necessitating prompt support with timber to avoid serious falls from the roof. After an extended examination of all the workings, it became clearly evident to me that lining with brick throughout was an absolute necessity, and that timbering would also be required for the entire length of the tunnel, with the possible exception of a distance of about 800 feet where a ledge of limestone, eight feet in thickness, could be utilized for the roof.

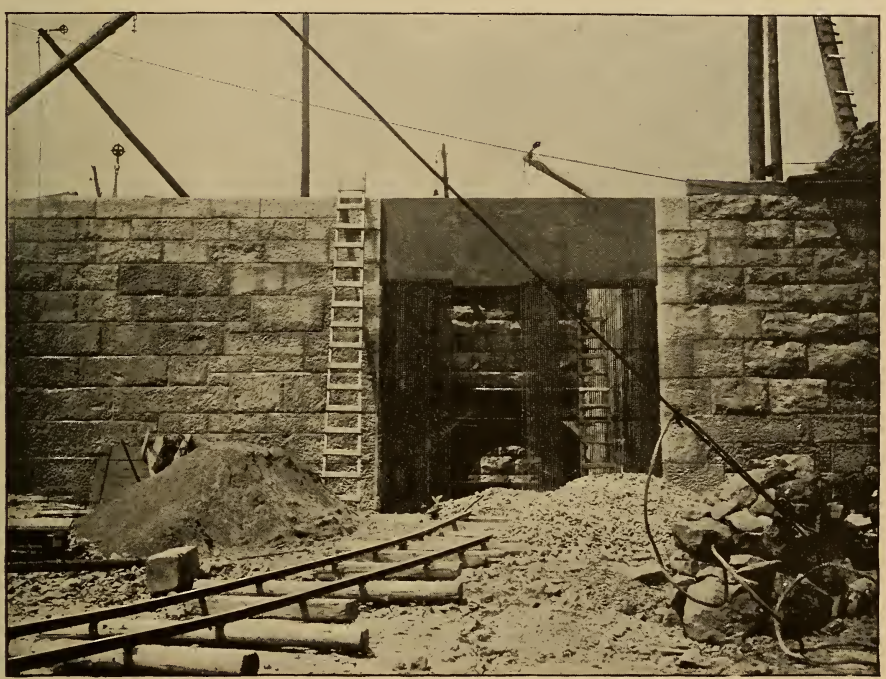
My report was rendered in accordance with these findings, and the subsequent construction fully confirmed the correctness of the recommendations. After making this report, and assisting in the remodeling of the construction contracts, I was invited to supervise the work, as resident consulting engineer, and, resigning my connection with the New York Aqueduct, I became established in that capacity at Niagara Falls early in the month of June. Upon the completion of the tunnel to the 6700-foot station, in January, 1893, I became chief engineer of the work, and of the companies allied to the Cataract Con-



THE TUNNEL DURING CONSTRUCTION.

struction Company, and continued in that capacity until the completion of construction in 1894. After the decision in regard to lining was made, the tunnel work was vigorously prosecuted by the contractors, until its completion, under the special supervision of Resident Engineer Porter and Division Engineer Mr. William S. Humbert.

The tunnel is lined throughout with exclusively for mortar in laying brick and stone masonry in the tunnel and wheel-pit. The composition of the mortar generally used was one part cement to three parts sand, but at the shafts and the wheel-pit, where the flow of water was very strong, the proportion was changed to one to two, and in some cases one to one. This bricking commenced in March, 1892, and fol-



ONE OF THE CANAL INLETS AT AN EARLY STAGE.

at least four rings of the best hard-burned brick, making a solid brick wall sixteen inches in thickness. At points where, from the nature of the material through which the tunnel was driven, it was thought possible that greater strength might be required, the thickness was increased to six and even eight rings.

The upper or face ring of the invert was laid with the best quality of vitrified paving brick. All spaces between the brick work and sides or roof of the tunnel were filled with rubble masonry. American Portland cement was used lowed the work of excavating as closely as was consistent with safety.

A very satisfactory method of lining the arch was adopted. The main feature was the construction of a platform about ten feet above the invert after the side walls were laid to as high a point as was convenient for the handling of brick and mortar. On this platform tracks were laid, and the brick and mortar were hauled to their destination, a separate landing being made in the shafts at the proper elevation. The great advantage of this system consisted in enabling the contractors to carry on the work of ex-

LOWERING A PENSTOCK INTO THE WHEEL-PIT.

cavating and of lining at the same time, without the possibility that the outgoing cars, loaded with material excavated in driving the tunnel, could interfere with cars coming in, loaded with brick and mortar, the brick work, at times, being carried on within less than 100 feet of the face of bench excavation in the tunnel.

At the portal it was decided to drop the grade of the invert about eleven feet below the average low water of the river thus permitting fully one-half the flow from the tunnel to discharge below the surface. To this end, the grade was changed into an ogee commencing at a point 90 feet from the portal, dropping nearly eleven feet in that distance.

This portion of the tunnel, to the elevation of the spring line, was lined with steel boiler plate, riveted to steel ribs three to four feet in depth, which were bedded solidly in Portland cement concrete, the arch being turned with brick except for 25 feet at the portal, where the construction was granite masonry. The masonry for this facade was carried solidly to a depth of 38 feet below the surface of water, when a ledge of white sandstone was struck, which was entirely satisfactory for a foundation.

The first contract was with Messrs. Rodgers & Clement, of New York City, for 6700 feet of tunnel with two main shafts and a smaller shaft at the bluff near the portal. This contract was completed in January, 1893. On January 5, 1892, a contract was made with A. C. Douglas, of Niagara Falls, for an extension of the main tunnel 300 feet further, making a total length of 7000 feet in main tunnel; for a tunnel connection of same size to the wheel-pit, and for the wheel-pit, and for a short tunnel, circular in shape and ten feet in diameter, providing for a possible development of lands owned by the company on the north side of the tunnel.

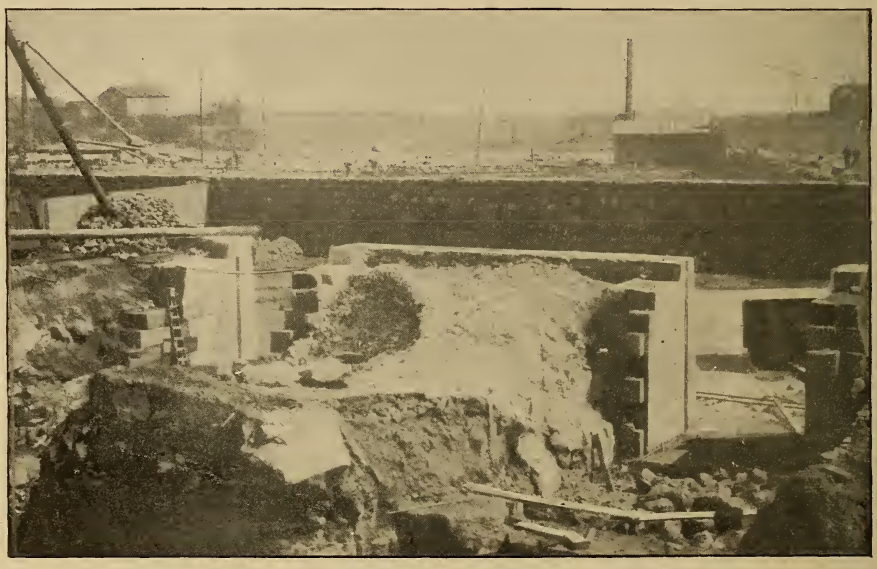
The wheel-pit, which is really an elongated shaft, is an uncommon feature in construction, particularly in its magnitude. The dimensions are: Length, 140 feet; width, 18 feet; depth, 178 feet. This pit is lined on the bottom with 16 inches of brick, the top course being of best quality paving brick, and

on the sides, to the height of 30 feet above the invert, with from two to two and a half feet of solid brick masonry. This wall is capped with a single course of limestone, two and one-half feet in thickness, on which the girders, weighing about twenty-five tons, are placed. These carry the weight of the penstocks and turbines, of 5000 horse-power each. It is intended ultimately to extend this wheel-pit to a length of about 400 feet.

The masonry construction of special interest is at the connections between the main tunnel and the side tunnels, and at the portal or place of discharge into the lower river. First in importance is the connection between two horseshoe arches, each 21 feet high and 18 feet 10 inches wide at the spring line, at an angle of 60 degrees; and second, the connection between a circular arch 10 feet in diameter and the horseshoe arch, also at an angle of 60 degrees. All designs and details for the connections were prepared by Mr. George F. Simpson, the chief draughtsman in this de-

THE MOUTH OF THE TUNNEL DURING CONSTRUCTION.

partment of the work. The Brandywine Granite Company, of Wilmington, Del., furnished all granite in this construction, cut into shape and to the dimensions required. The arches for the connection with the tunnel were laid by the contractor under the direct supervision of Mr. J. G. Tait, assistant engineer, who found all preparatory work so accurately done that practically no difficulties were encountered, except such mechanical ones as would naturally with two lines of crib-work filled with stone, the outer one 12 feet in width, the inner one 10 feet in width, with an intervening space of 8 feet, which was carefully lined on each side with sheet piling. After the piling was completed, the loose and sandy material was removed to a hard clay bottom by the use of a centrifugal pump, and the space was then filled with clay which was dumped into the water and worked as much as possible. This dam was prac-



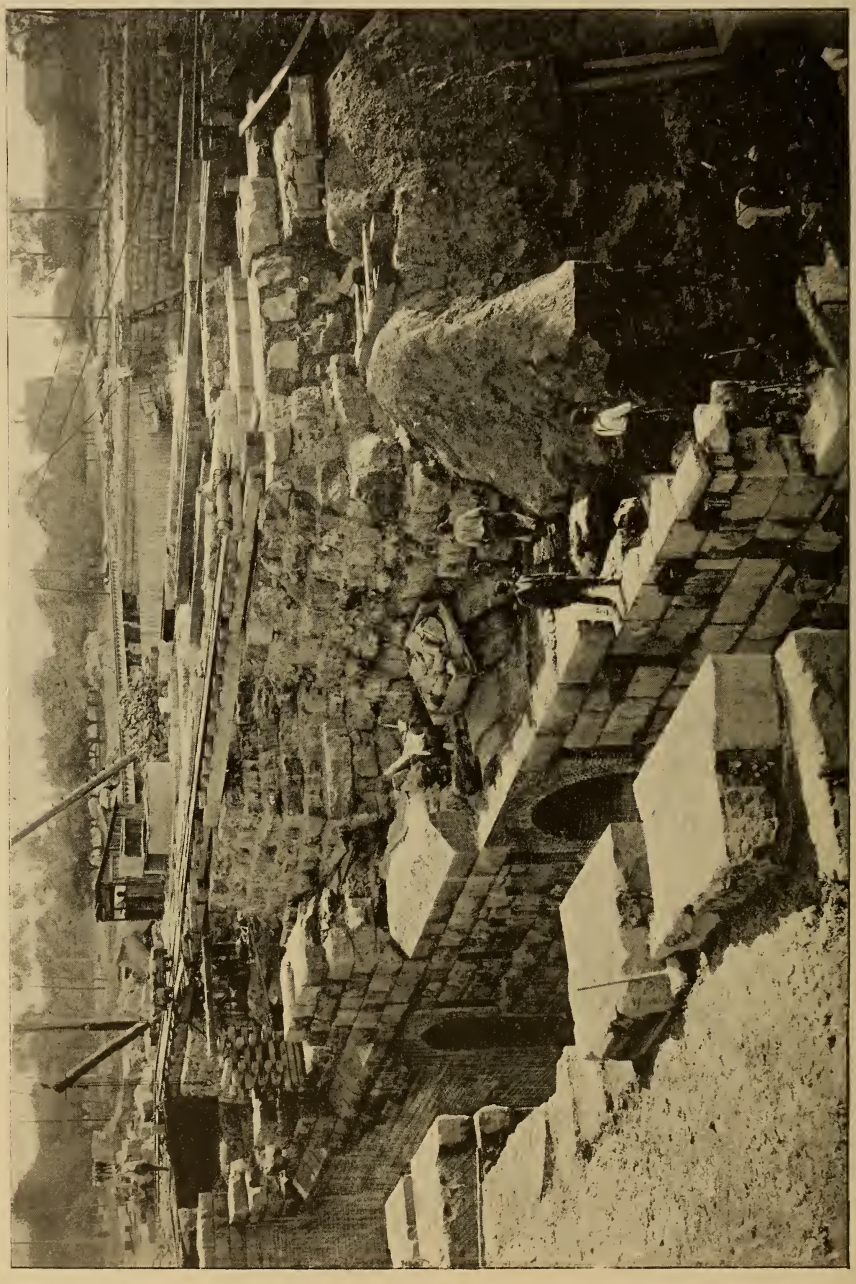
A PROGRESS VIEW OF THE CANAL.

be expected in constructing arches of that massive character in tunnels, allowing an average clearance not exceeding one foot.

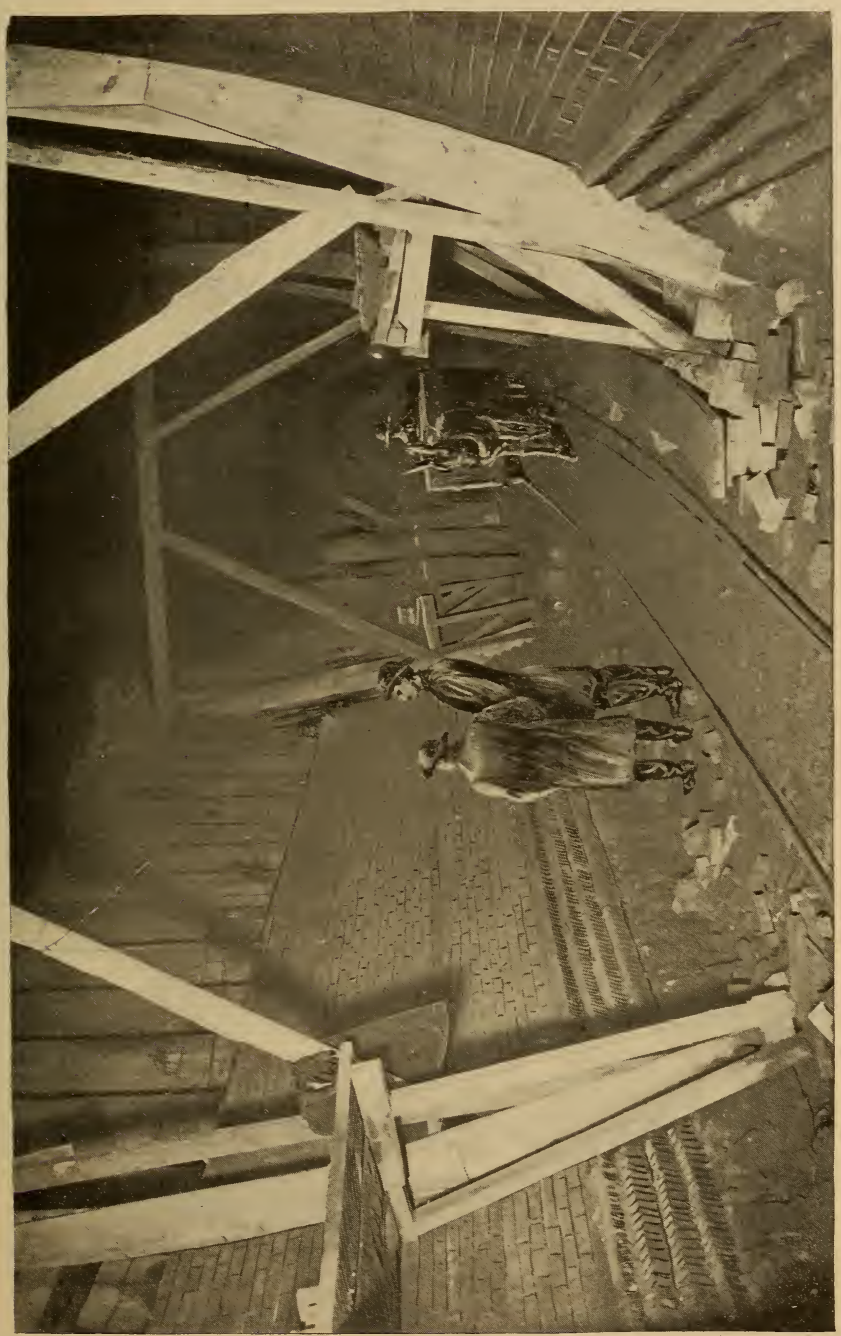
In August, 1891, work had been commenced, with a company force under the direct management of myself, on the main and inlet canals. The mouth of the canal is 600 feet from the shore line, necessitating the construction of embankments on each side for that distance into the river. After these embankments had been extended to the proper places, a coffer dam, 450 feet in length, was thrown across the mouth and connected with the ends of these embankments. This coffer dam was constructed tically water-tight and remained in perfect condition until removed in the spring of 1894. One leak, which gave trouble for several hours, was due to an imperfect connection with the side dump from the shore at the east end of the dam. No delay in the work of excavation or of laying masonry was, however, experienced from this cause.

The side walls of the canal are of solid masonry, 17 feet high, 3 feet thick at the top and about 8 feet at base. This work was laid in ordinary American cement mortar, composed of one part of cement and two parts of sand. The excavation and masonry were carried on simultaneously, and the canal was

ANOTHER EARLY VIEW OF THE TUNNEL'S MOUTH.



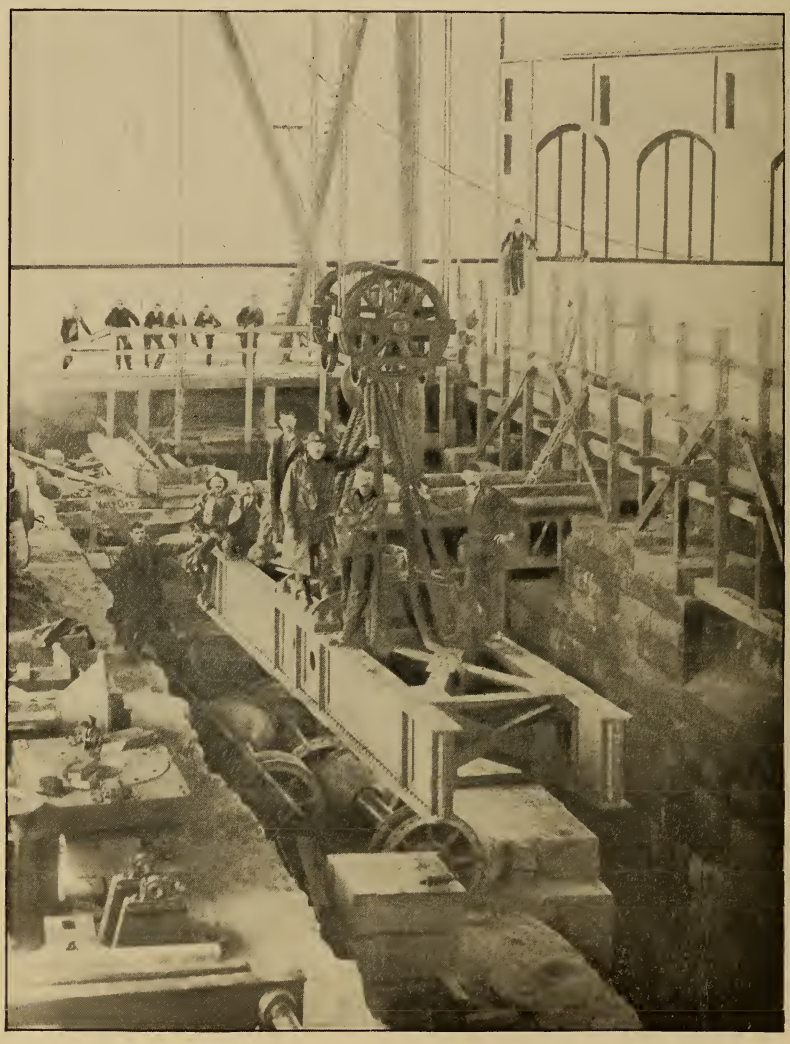
A VIEW OF THE WHEEL-PIT DURING CONSTRUCTION.



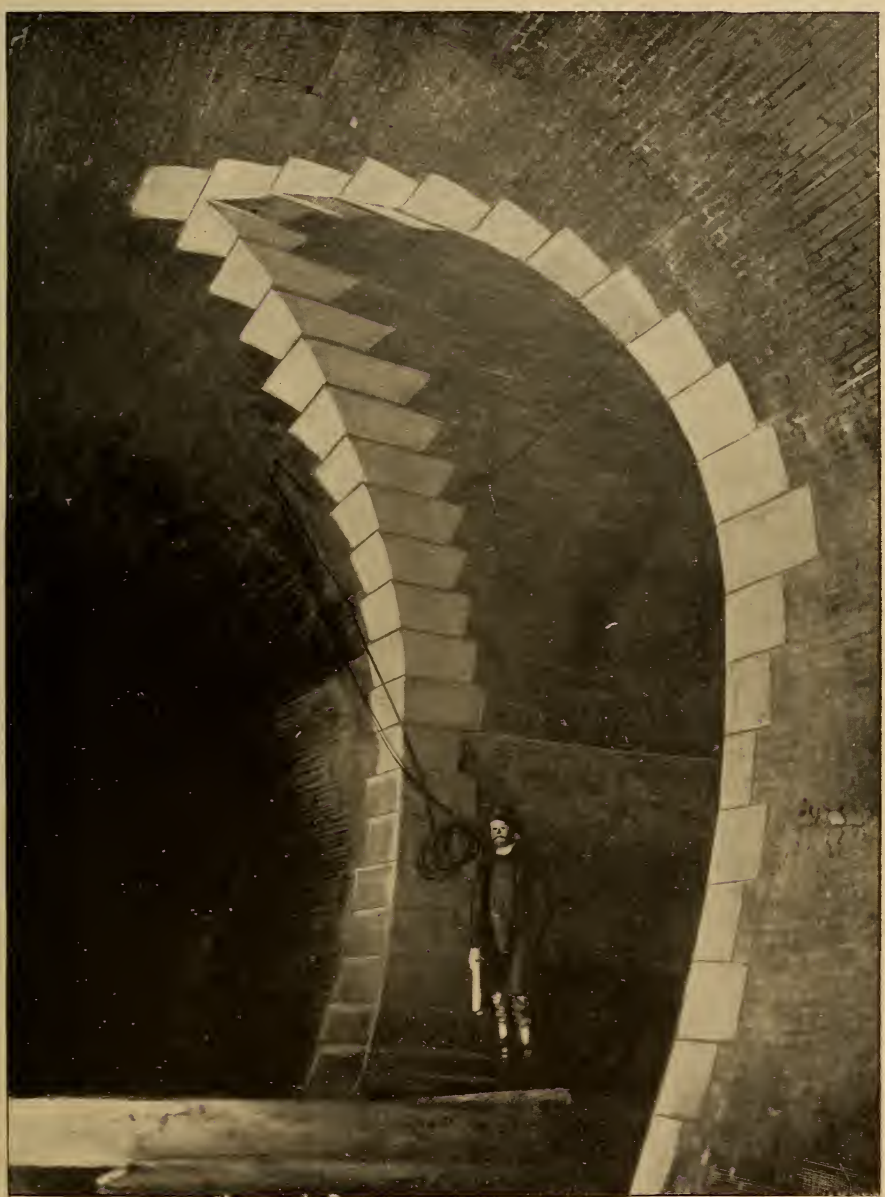
A TUNNEL VIEW, SHOWING THE METHOD OF LINING WITH BRICK.

completed in October, 1892. The canal carries twelve feet depth of water at the ordinary low stage of the river.

During the year 1892–93, the Niagara Junction Railway was constructed, which runs through the entire length of the property owned by the various corporations allied in interest. This railway connects with all the trunk lines, and extensive docks have been constructed on the Niagara River, on which its rails are laid, making connection with the traffic of the Great Lakes. By this railway, materials and freights are received from, and delivered to, all the manufacturing sites which this development opens to the public. During the same time a new water-works plant was established with a capacity of 6,000,000 gallons per day, the water being taken from the Niagara River one mile above the falls.



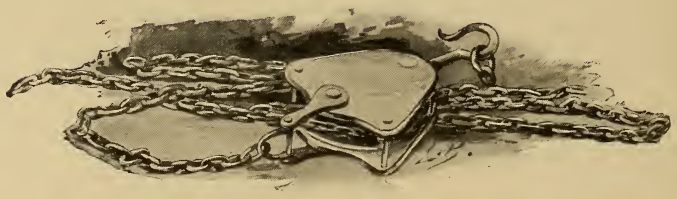
GETTING READY FOR THE TURBINES.

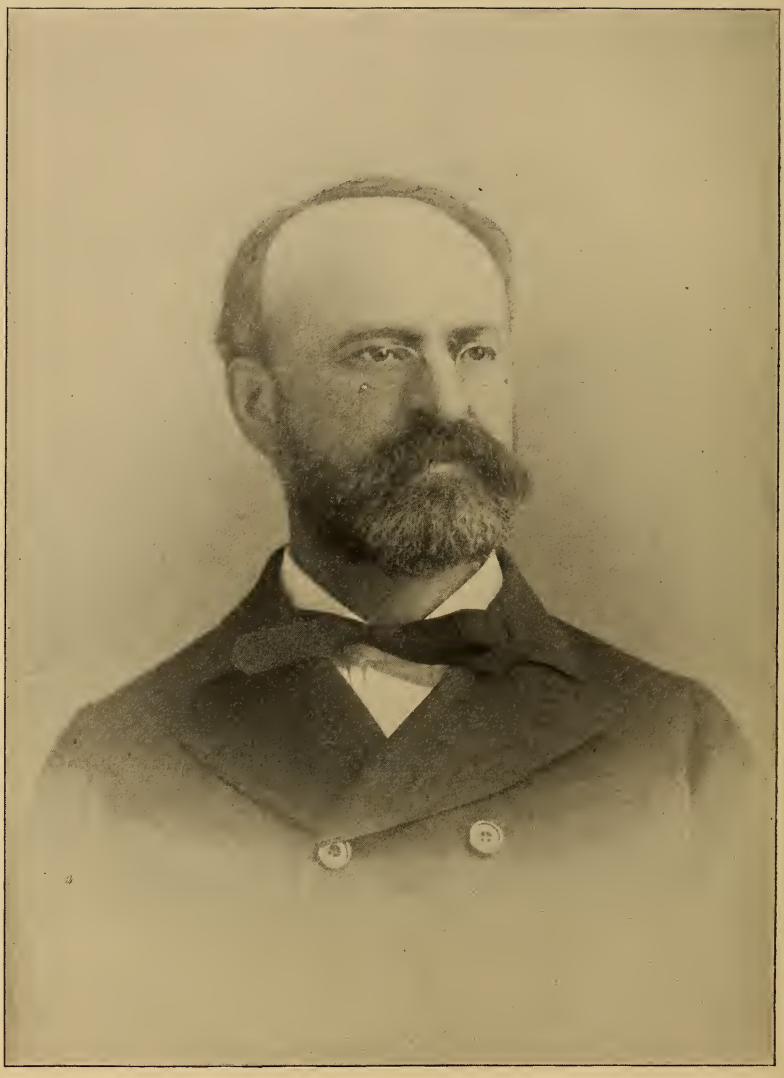


A LATERAL TUNNEL JUNCTION.

Accommodations have also been provided for operatives, by the erection of 50 handsome and convenient cottages, with fine macadam streets, a complete system of drainage and sewerage, with disposal works and unlimited water supply. Of this work, as well as of the water-works and railway construction, Division Engineer Mr. William A. Brackenridge was in special charge.

A handsome power house has been completed over the wheel-pit, after designs by Messrs. McKim, Mead & White, of New York City, the contractors being Messrs. James Stewart & Co., of St. Louis and Buffalo. The outer surface is of limestone, and the inner, for a height of six feet from the floor, is of enameled brick, and above that of ordinary brick, coated with white enamel paint. In this building, which is 200 feet in length, a 50-ton traveling crane transferred the machinery for the turbines from the cars to their location in the wheel-pit. The greatest number of men employed at any one time was about 2500. In the construction 600,000 tons of material were removed, and there were used 16,000,000 bricks, 19,000,000 feet of timber and lumber, 60,000 cubic yards of stone, 55,000 barrels of Giant American Portland cement, 12,000 barrels of natural cement and 26,000 cubic yards of sand.



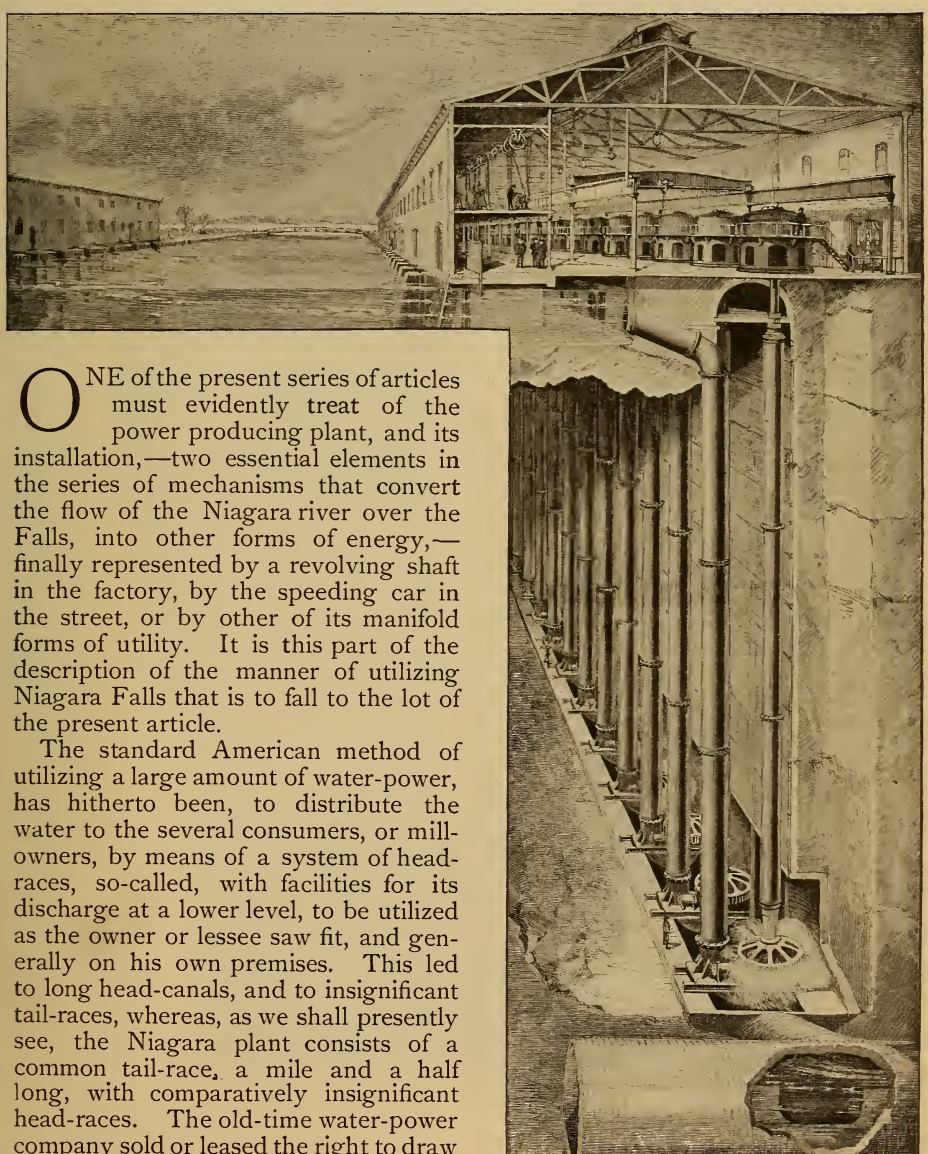


Clemens Herschel

CLEMENS HERSCHEL was consulting hydraulic engineer of the Cataract Construction Company during the period of construction.

NIAGARA MILL SITES, WATER CONNECTIONS AND TURBINES.

By Clemens Herschel, Hydraulic Engineer.



ONE of the present series of articles must evidently treat of the power producing plant, and its installation,—two essential elements in the series of mechanisms that convert the flow of the Niagara river over the Falls, into other forms of energy,—finally represented by a revolving shaft in the factory, by the speeding car in the street, or by other of its manifold forms of utility. It is this part of the description of the manner of utilizing Niagara Falls that is to fall to the lot of the present article.

The standard American method of utilizing a large amount of water-power, has hitherto been, to distribute the water to the several consumers, or mill-owners, by means of a system of head-races, so-called, with facilities for its discharge at a lower level, to be utilized as the owner or lessee saw fit, and generally on his own premises. This led to long head-canals, and to insignificant tail-races, whereas, as we shall presently see, the Niagara plant consists of a common tail-race, a mile and a half long, with comparatively insignificant head-races. The old-time water-power company sold or leased the right to draw

BY SPECIAL ARRANGEMENT WITH DR. F. P. VAN DENBERGH, BUFFALO, N. Y.

A BIRDS'-EYE VIEW AND SECTION OF THE NIAGARA INSTALLATION.

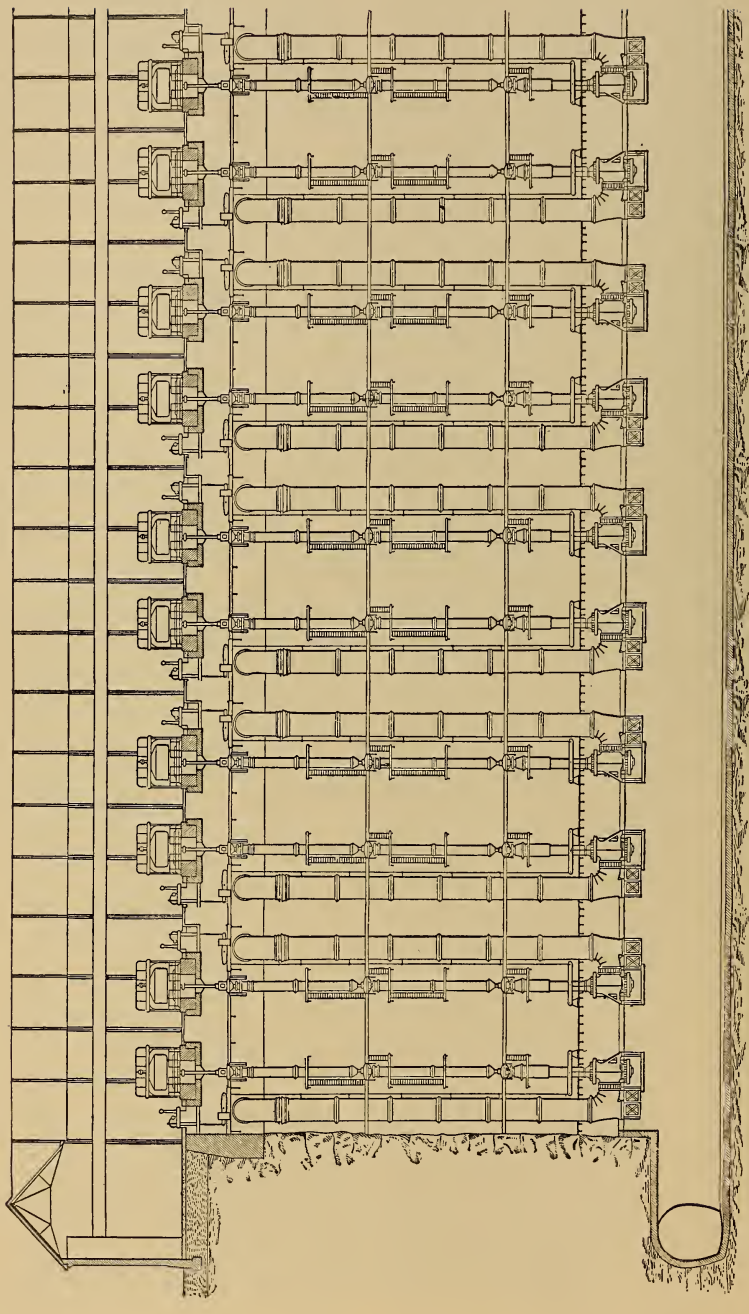
a definite quantity of water, at defined times, with the privilege of discharging it at a lower level, and the mill-owner did the rest; whereas, at Niagara Falls, the right is leased to discharge a definite quantity of water into the tail-race tunnel, with the privilege of drawing this quantity from the head-canal, or from the river. But over and above this the product,—power,—may be contracted for at Niagara Falls, delivered on the shaft.

To create a large group of mill-sites of the older sort, there was necessary, in the first instance, a large continuous body of land, properly located for the purpose. If this could not be bought up secretly, and in large blocks, the whole water-power enterprise would fail to come to fruition. In Europe, however, several such enterprises came into being in spite of the inability of the projectors to primarily buy tracts of land such as have been described. This was done by establishing central power stations near the dam, or head canal, and then transmitting the power produced, instead of the water to produce it, to the consumers, or mill-owners. Up to within say five years, this had always been accomplished by means of wire-rope transmissions of power, and it is easy to see that the invention of the electrical transmission of power would give this form of the utilization of a large water-power a great impetus. Many such plants are, therefore, already in existence, many are building, but among them all, no one is probably so celebrated, and is attracting the attention of all intelligent men as this at Niagara Falls.

The work at Niagara Falls is designed to be utilized in both of the methods above described, and examples of both methods of distributing power are built. The plant of the Niagara Falls Paper Company is an example of the first and older method of power utilization, while the Central Power Station of the Niagara Falls Power Company is the grandest example yet undertaken of the second described, and the later method of power distribution. The Niagara Falls Power Company also owns some 1200 acres of land adjoining the Central Power Station and the present head canal, all of which can be utilized for the sites of manufacturing establishments by one or the other of the methods described. This has been laid out in streets and blocks, with a freight railroad, to be spoken of presently, connecting the mill sites with all the trunk lines that pass Niagara Falls, and adjoins the residential district being developed by the Niagara Development Company, whose first fruits are the village called Echota, and the adjoining wharf and other property. But over and beyond all this, a transmission of power to Buffalo, only 20 miles off, and possibly still further, is within the scope and design of the Central Power Station now building.

It is interesting to find how the work of to-day was dreamt of in 1876. In that year the late Sir William Siemens came to America to see the Centennial exhibition. Proceeding to Niagara Falls, he was struck with its capabilities as a power-producing centre, and carried out what was probably the first computation ever made of the cost of distributing power from Niagara Falls to the country around it by electricity. In the "Life of Sir William Siemens," by William Pole, this subject is treated at length, and the following quotation from it may be interesting in this place:

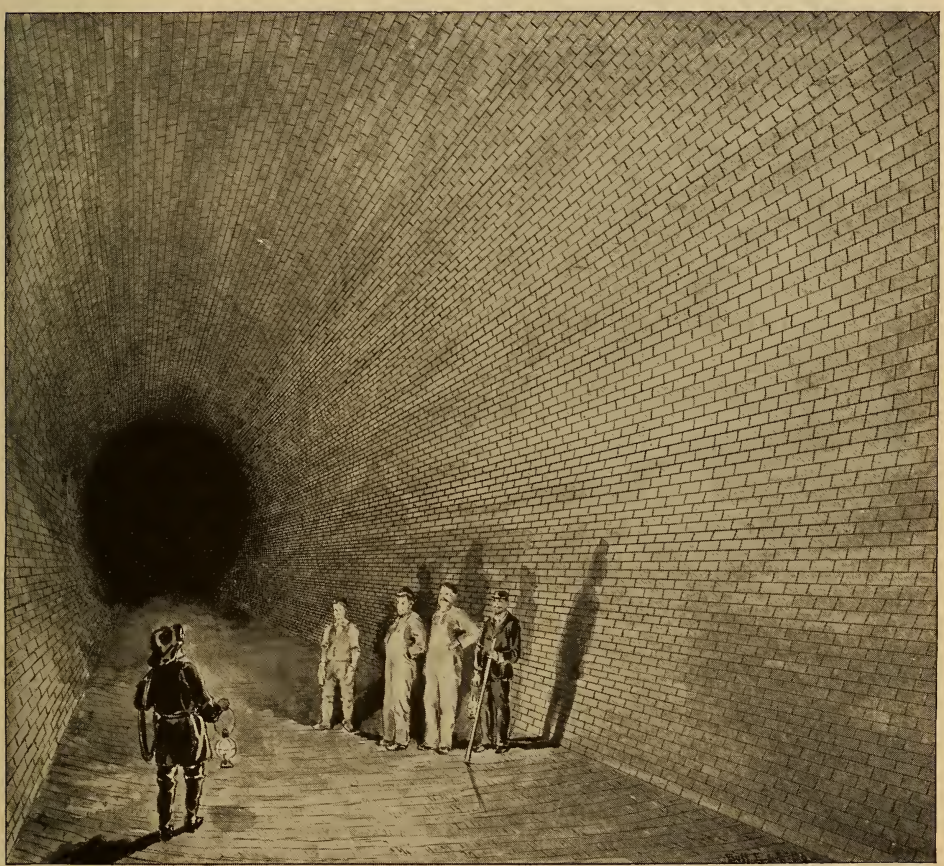
"When such a machine as a dynamo was once brought into existence, it was sure to be taken advantage of for other applications of powerful electric energy. * * * It is necessary here to allude to one remarkable case which was among the earliest to which Dr. Siemens gave his attention. In this the electric current is used, not for action of its own, but merely as a vehicle for the transmission of power; just as a boat on a river, or a wagon on a railway is used to transport some valuable commodity for use at a distant place. The power of horses, or of a water-fall, or of a steam engine, is applied in a dynamo to excite a current; that current is passed along a wire, and will, by the aid of another dynamo at the other end of the wire, reproduce the power (or a



SECTIONAL ELEVATION OF THE POWER HOUSE AND WHEEL-PIT OF THE NIAGARA FALLS POWER COMPANY, TO CONTAIN TEN 5000 HORSE-POWER ELECTRIC GENERATORS AND TEN 5000 HORSE-POWER TURBINES.

portion of it) in a far distant locality.

"This use of electricity formed a favorite study for Dr. Siemens, and it seems to have first strongly impressed itself on his mind when, in the autumn of 1876, he went to America and visited Niagara Falls. In all his many journeys in different countries nothing made such a deep impression on him as this



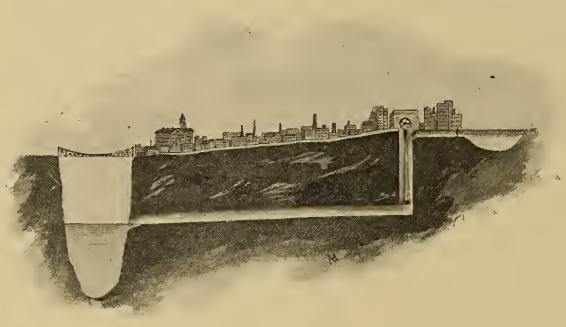
IN THE MAIN TUNNEL.

wonderful natural phenomenon. The stupendous rush of waters filled him with fear and admiration, as it does every one who comes within the sound of its mighty roar. But he saw in it something far beyond what was obvious to the multitude, for his scientific mind could not help viewing it as an inexpressible manifestation of mechanical energy. And he at once began to speculate whether it was absolutely necessary that the whole of this glorious magnitude of power should be wasted in dashing itself into the chasm below—whether it was not possible that at least some might be practically utilized for the benefit of mankind?

"He had not long to think before a possible means of doing this presented itself to him. The dynamo machine had just then been brought to perfection, partly by his own labors; and he asked himself, why should not this colossal power actuate a colossal series of dynamos, whose conducting wires might transmit its activity to places miles away? This great idea, formed

amid the thunderings of the cataract, accompanied him all the way home, and was meditated on in the quiet of his study. He submitted it to the test of mathematical calculation, and so far convinced himself of its reasonable nature, that he determined, when a fitting occasion arrived, to make it known.

"The opportunity arrived in the spring of 1877, when he had to give an opening address as president of the Iron and Steel Institute. In that address he had to point out the dependence of the iron and steel manufacture on coal as a fuel. He alluded to the gradual diminution of the stores in the earth of this valuable commodity, owing to the vast consumption of it for steam-power, and he urged that other natural



THE GENERAL POWER PLAN.

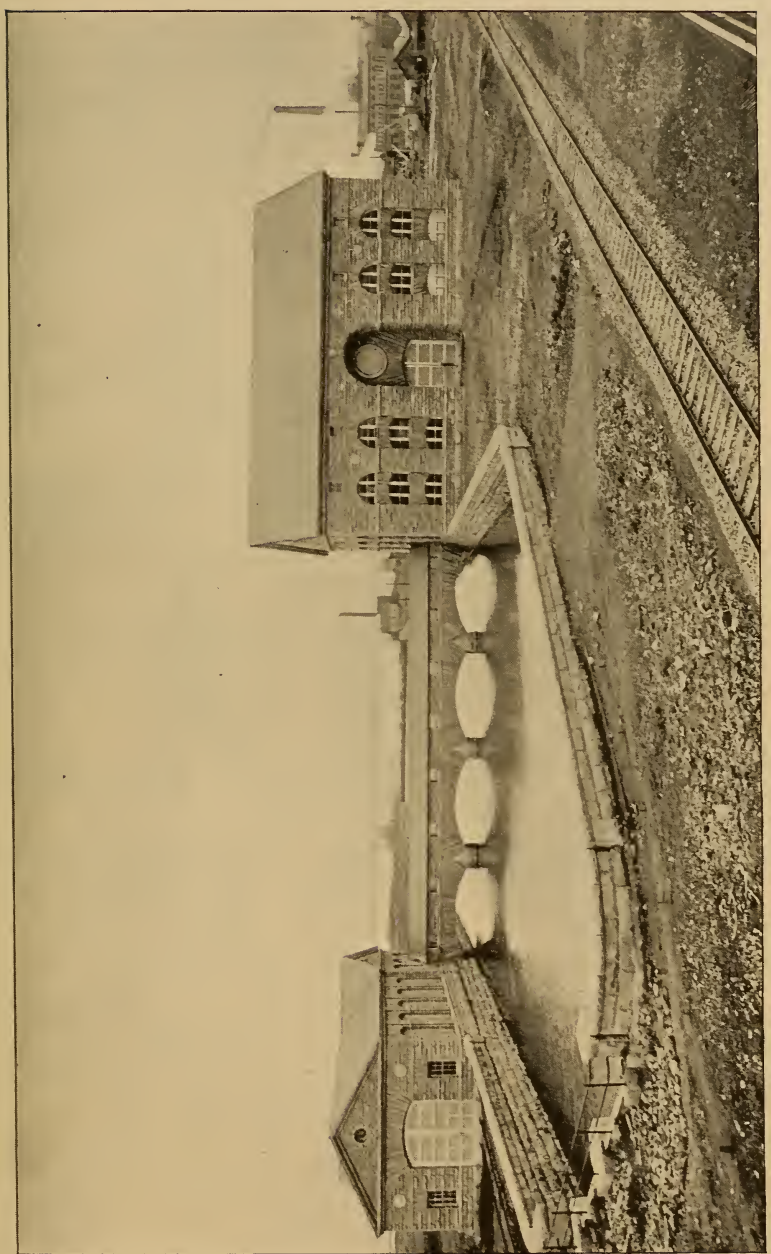
sources of force, such as water and wind, ought to be made more use of. And speaking of water-power, he made the following remarks:

"'The advantage of utilizing water-power applies, however, chiefly to Continental countries, with large elevated plateaus, such as Sweden and the United States of America, and it is interesting to contemplate the magnitude of power which is now for the most part lost, but which may be, sooner or later, called into requisition. Take the Falls of Niagara as a familiar example. The amount of water passing over this fall has been estimated at 100,000,000 of tons per hour, and its perpendicular descent may be taken at 150 feet, without counting the rapids, which represent a further fall of 150 feet, making a total of 300 feet between lake and lake. But the force represented by the principal fall alone amounts to 16,800,000 horse-power,* an amount which, if it had to be produced by steam, would necessitate an expenditure of not less than 266,000,000 tons of coal per annum, taking the consumption of coal at 4 pounds per horse-power per hour. In other words, all the coal raised throughout the world would barely suffice to produce the amount of power that continually runs to waste at this one great fall.

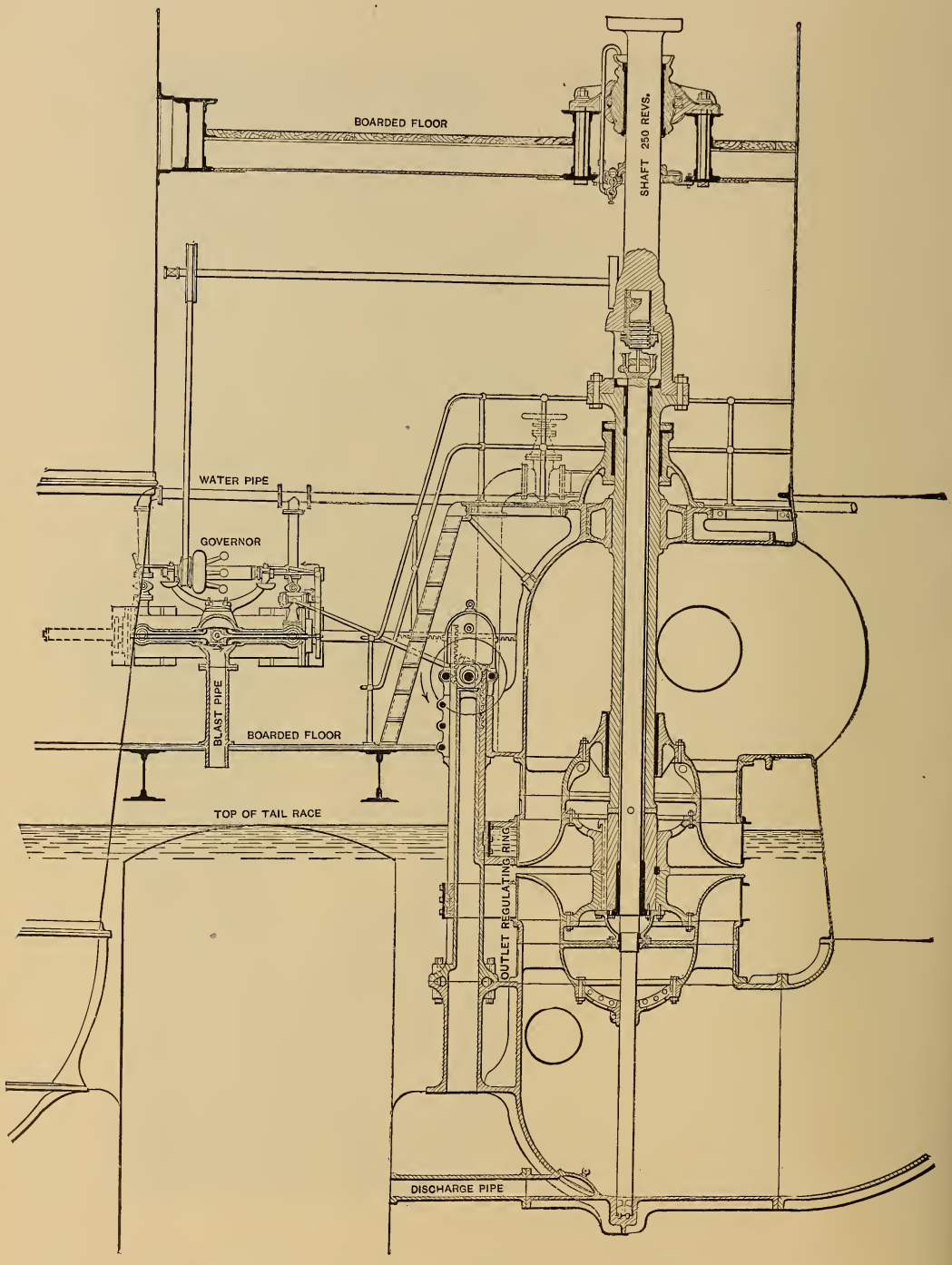
"'It would not be difficult, indeed, to realize a large portion of the power so wasted, by means of turbines and water-wheels erected on the shores of the deep river below the falls, supplying them from races out along the edges. But it would be impossible to utilize the power on the spot, the district being devoid of mineral wealth, or other natural inducements for the establishment of factories. In order to render available the force of falling water at this and hundreds of other places similarly situated, we must devise a practicable means of transporting the power. Sir William Armstrong has taught us how to carry and utilize water at a distance, if conveyed through high-pressure mains, and compressed air has been employed for the same purpose. At Schaffhausen, in Switzerland, as well as at some other places on the Continent, power is conveyed by means of quick-working steel ropes passing over large pulleys; by these means it may be carried to a distance of one or two miles without difficulty.

"'As regards electrical transmission, suppose water-power be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large me-

* The gaugings of the United States government engineers give an average discharge of about 275,000 cubic feet per second, which, with a fall of 216 feet, —the difference of elevation between the water above the rapids and that of the lower river—gives a total of 6,750,000 theoretical H.-P.—THE EDITOR.



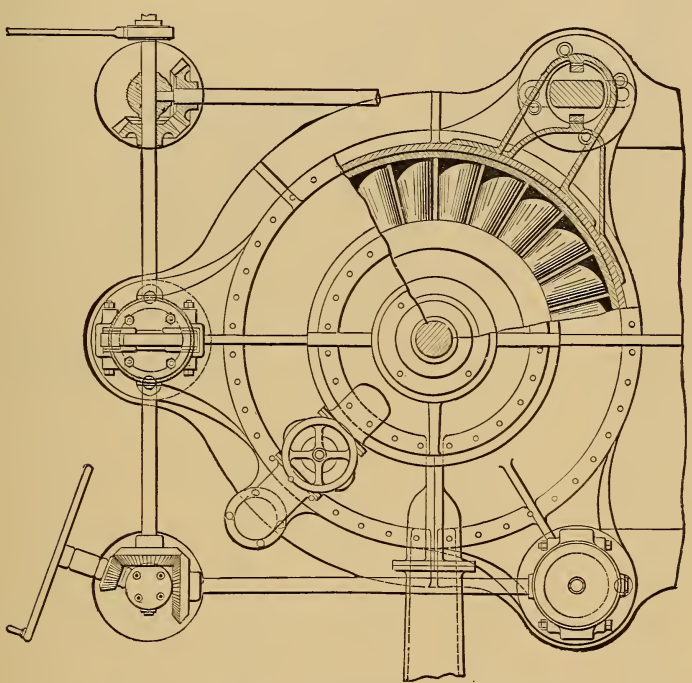
THE MAIN POWER STATION AND THE TRANSFORMER HOUSE, WITH CONNECTING BRIDGE.



SECTION OF WHEEL AND GOVERNOR DESIGNED BY ESCHER, WYSS & CO.

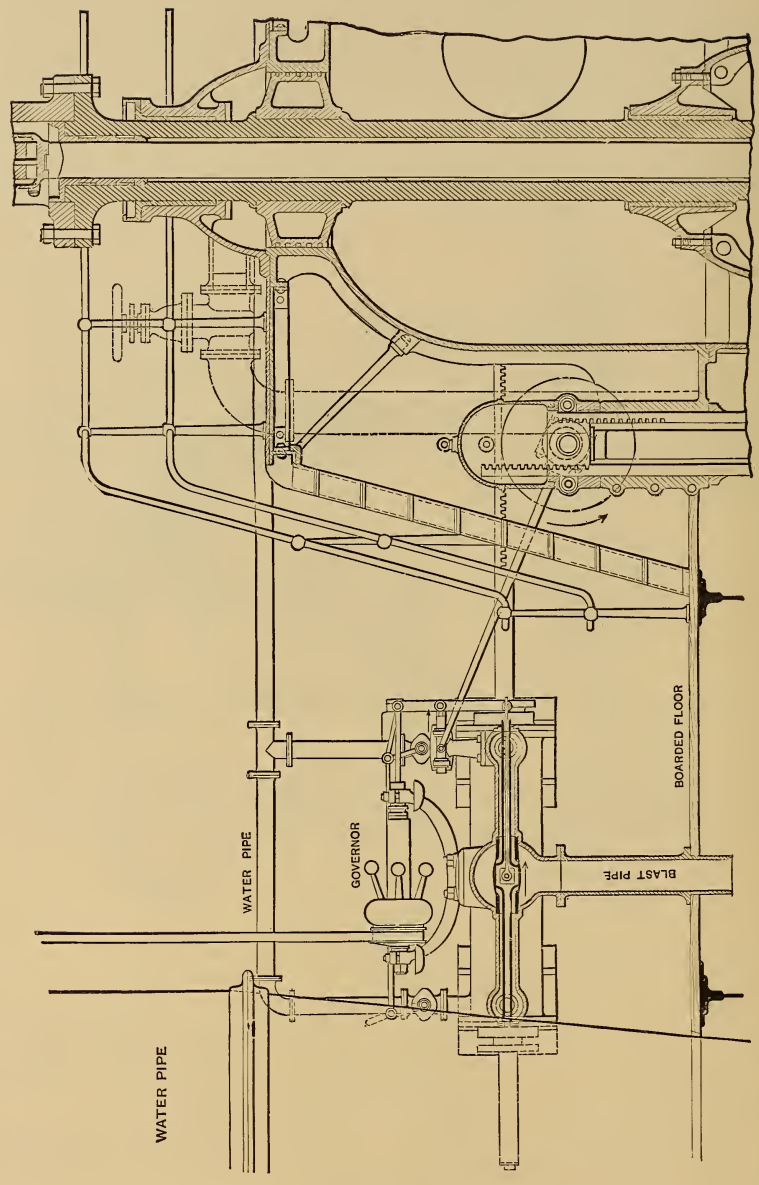
tallic conductor, and then be made to impart motion to electro-magnetic engines, to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod, three inches in diameter, would be capable of transmitting 1000 horse-power a distance of, say, thirty miles, an amount sufficient to supply one-quarter of a million candle-power, which would suffice to illuminate a moderately sized town.' This statement startled the audience considerably; and it is still remembered that, when it was delivered, a smile of incredulity was observed to play over the features of many of his hearers.''

One of the neatest and most valuable attributes of the Niagara Falls Power Company's mill sites is the road of the Niagara Junction Railway Company. Niagara Falls is already, or is destined to be, one of the great railroad centres of the United States. Two railroad bridges cross the river there, each used by several East and West trunk lines, and other such bridges are already talked of. Railroad freight rates are in competition with each other, and with lake and canal rates, and are to-day no greater from Niagara Falls to New York and to Boston, than they are from the established manufacturing centres of the East to these cities, while they are, on the other hand, very materially less from Niagara Falls to the great cities of the West, Southwest and South than they are from these same older manufacturing centres. The present favorable conditions will bring more manufacturing into the Buffalo and Niagara Falls district, and, as such things always operate, will also bring in still other trunk lines of railroad.

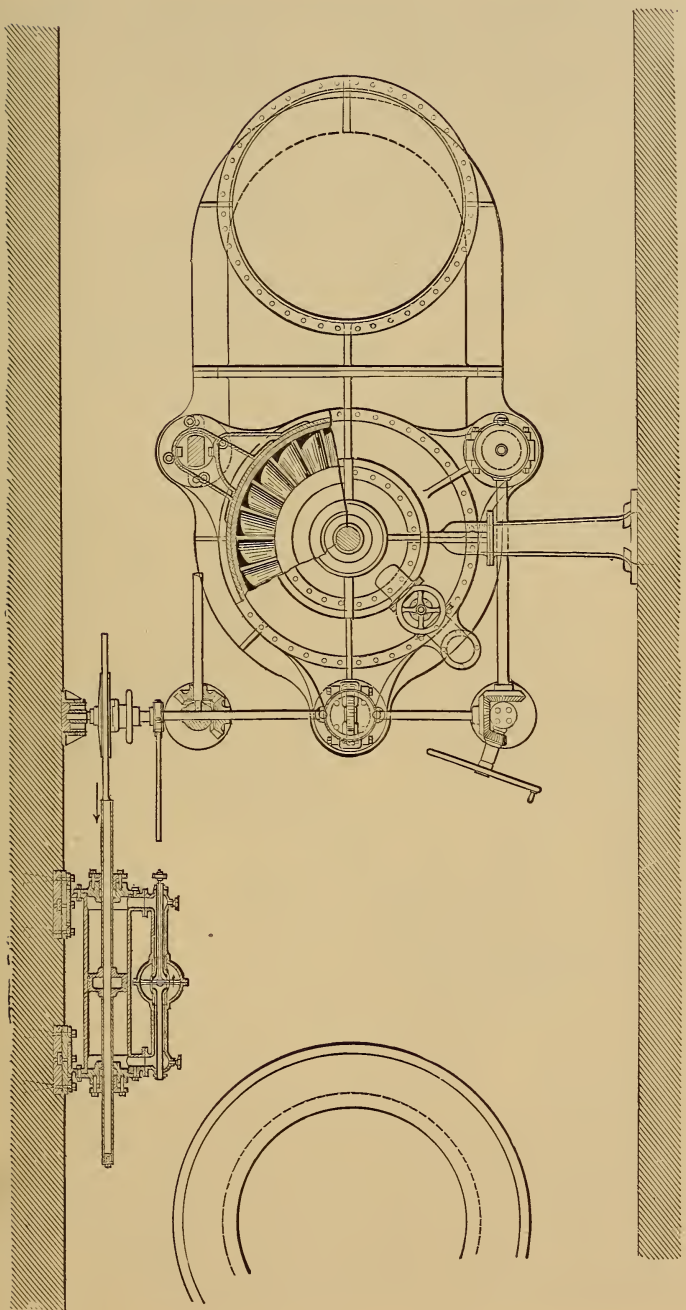


SECTION AND PLAN OF ESCHER, WYSS & CO.'S WHEEL.

It is for the purpose of enabling the occupant of any mill-site of the Niagara Falls Power Company to receive cars shipped to him by any line of railroad entering the Buffalo-Niagara Falls district, and of delivering cars directly to any such railroad, that the Niagara Junction Railway Company was organ-



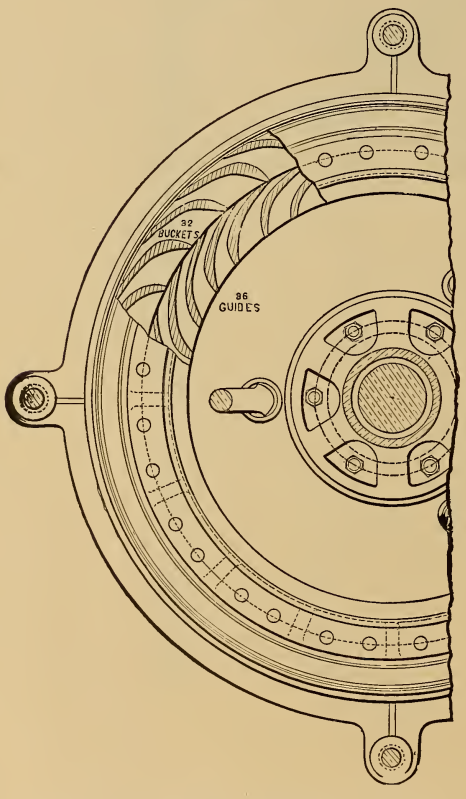
SECTION OF GOVERNOR DESIGNED BY ESCHER, WYSS & CO.



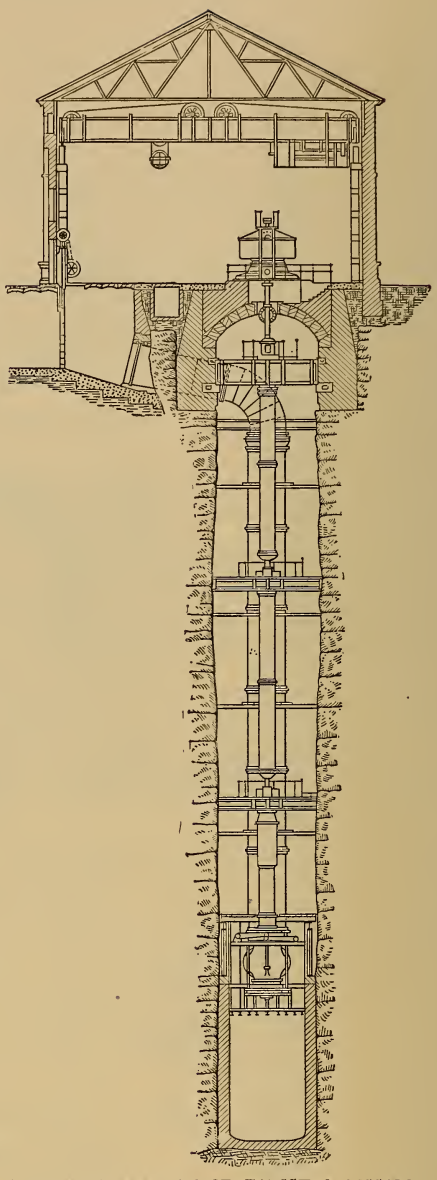
ANOTHER PLAN OF THE WHEEL DESIGNED BY ESCHER, WYSS & CO.

ized and the road built. It is an allied enterprise of the Niagara Falls Power Company and will do no little in furthering the growth and business of the new city, benefiting, in turn, all the trunk lines that do now or will, eventually, traverse the Niagara Falls neck of land between Lake Erie and Lake Ontario. Lake transportation, and transportation on the Erie Canal are, however, also available to the occupants of these mill-sites. Many of them front directly on the Niagara river, where it is navigable, and none of them are any great distance from it.

It will not be necessary to say much more on the subject of water connections at the Niagara mill-sites. The Niagara Falls Paper Company has a square wheel-pit, which is connected with the main tunnel tail-race by a branch tail-race, 7 feet in diameter. All dimensions of underground work are

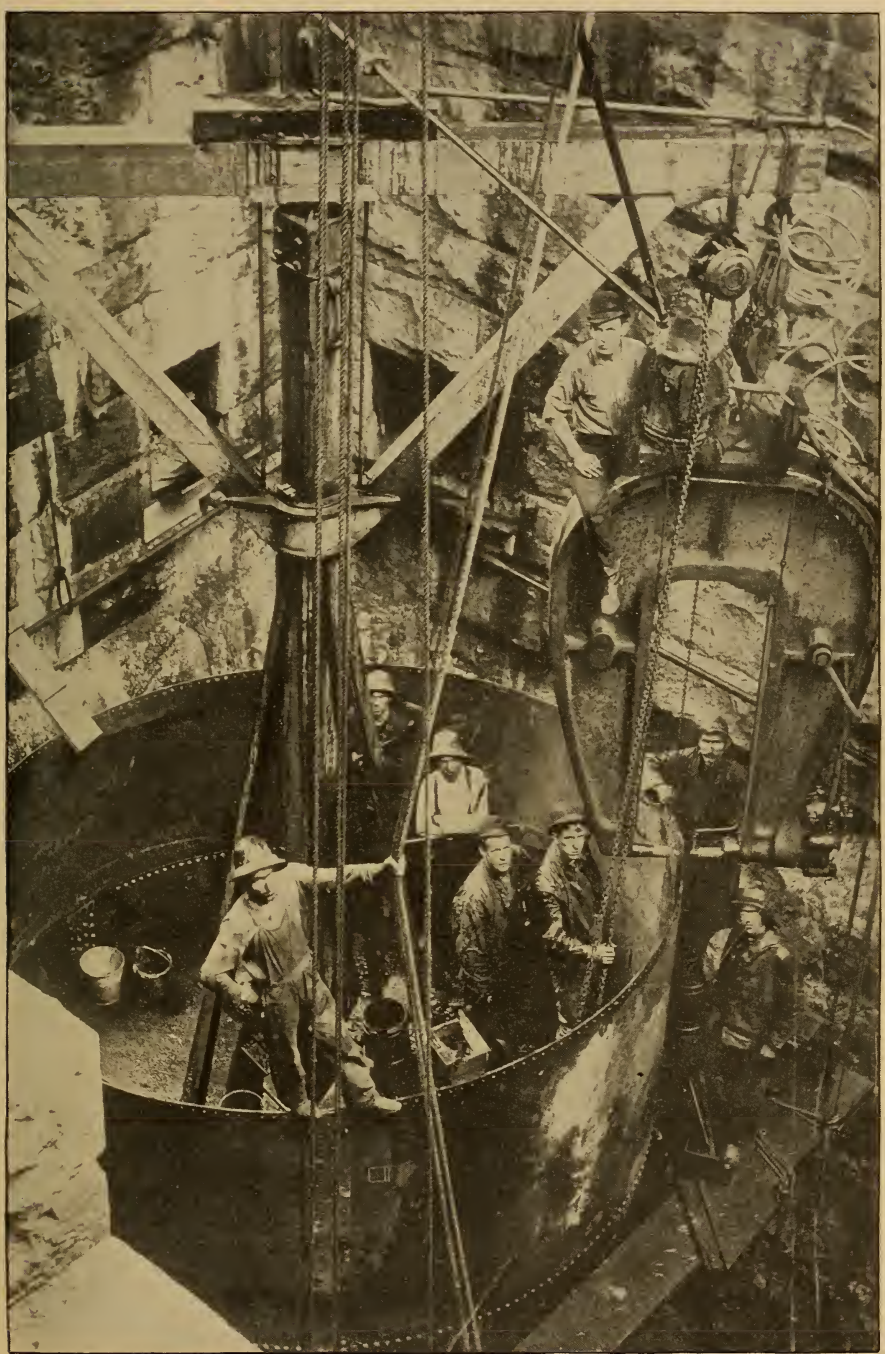


HALF SECTIONAL PLAN OF WHEEL DESIGNED BY FAESCH & PICCARD.

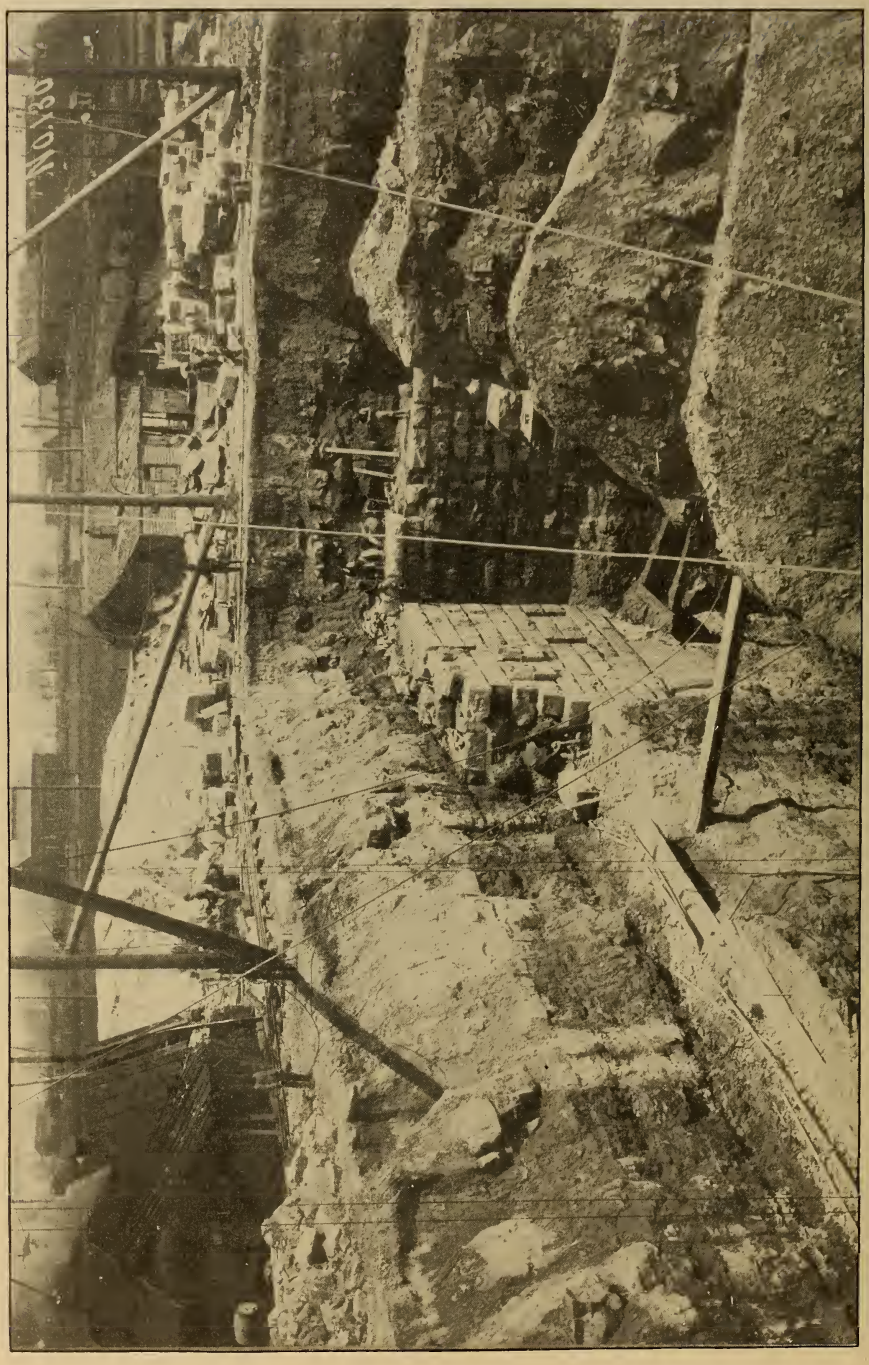


GENERAL ELEVATION OF FAESCH & PICCARD DESIGN.

kept as small as possible at Niagara Falls, to economize rock excavation, as, for example, the branch tail-race just mentioned. Fall being a commodity of less than the usual value on these mill-sites, it is economy to spend some of it toward reducing cross sections. This produces high velocities, but the tail-races are built of first-class materials,



RIVETING UP THE PENSTOCK OF THE NIAGARA FALLS PAPER COMPANY'S PLANT.

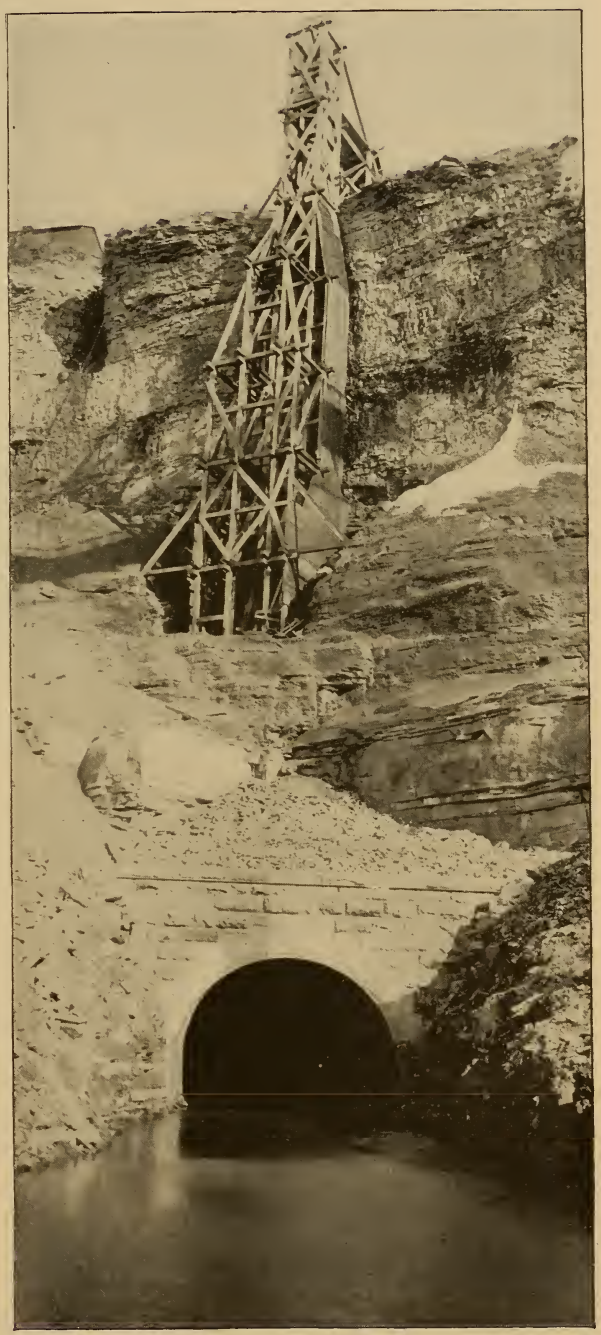


A VIEW OF THE WHEEL-PIT DURING AN EARLY STAGE OF CONSTRUCTION.

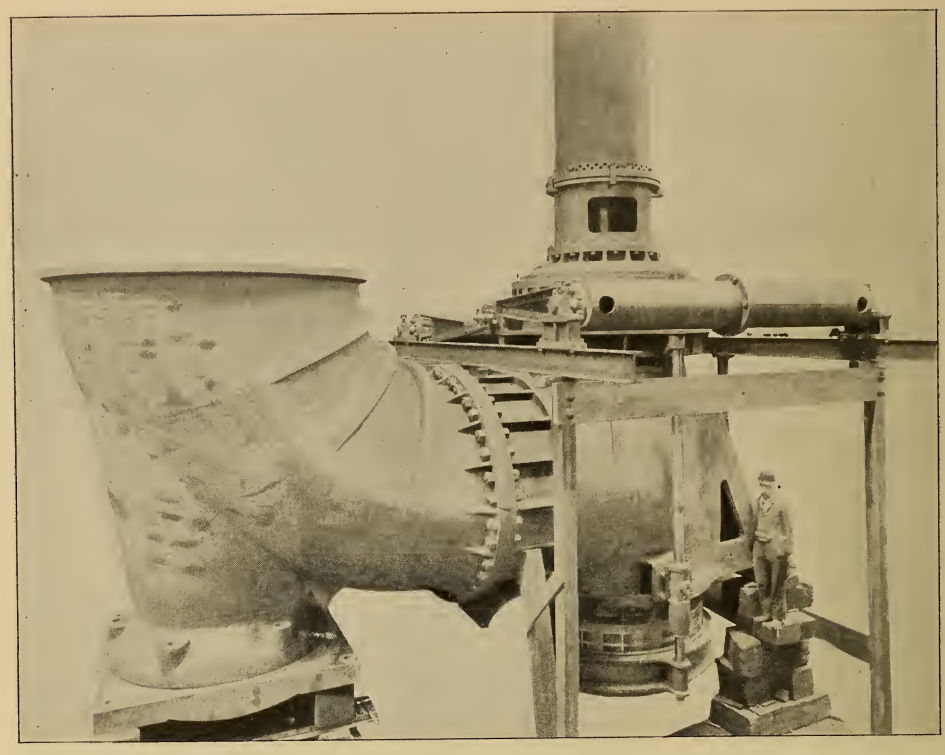
and are set in a rock excavation. The water used carries no sand, and experience has already shown that the tailraces line themselves with a layer of slime in spite of the great velocity in them. So long as this slime adheres to the brick and to the cement joints, there can evidently be no wear of the brick masonry lining.

The wheel-pit of the Niagara Falls Power Company is a long slot cut in the rock, instead of a group of small wheel-pits, and to save excavation, though at the cost of some fall wasted, the wheels are set on plate-girder bridges spanning the slot, and so as to leave a tail-race beneath the plate girders. This tailrace, or bottom of the slot, is connected by a short curve with the main tail-race tunnel.

The fashionable turbine of the present day, in the United States, is, no doubt, the twin turbine, with horizontal axis, this axis projecting from the wheel case, at one or both ends, and either driving its attached machine directly, or carrying a pulley, to belt from. Several attempts were made to fit this general form of motive power for the case in hand. These all failed from the great space required for the belts or drive-ropes, which, in this case, would have had to be gained at the price of a material increase in the amount of rock excavation. Not to transmit the power to the surface of the ground and to attach the machinery underground, brings with it the necessity of excavated chambers 140 feet below



THE MOUTH OF THE TUNNEL.



ONE OF THE NIAGARA POWER COMPANY'S 5000 HORSE-POWER TURBINES DESIGNED BY FAESCH & PICCARD, GENEVA, SWITZERLAND. BUILT BY THE I. P. MORRIS CO., PHILADELPHIA, PA., U. S. A

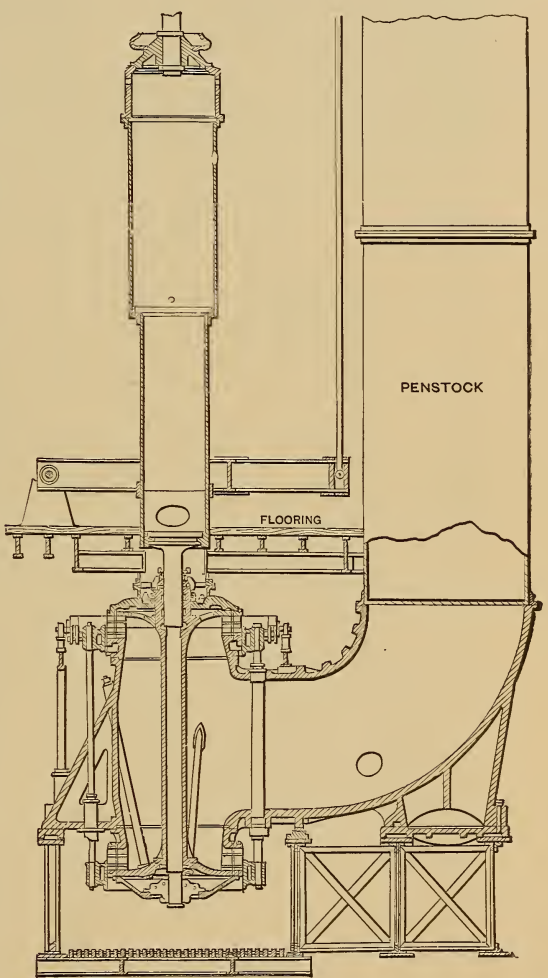
the surface, liable to be damp, or wet, and requiring constant artificial light; in short, forming a likewise undesirable arrangement. These considerations led, therefore, in the case of the Central Power Station of the Niagara Falls Power Company, to wheels with vertical shafts, and, as has been described, to rows of such wheels, set in a continuous slot, directly over the appurtenant tail-race; and to a group of such wheels, set in a square pit, for the Niagara Falls Paper Company.

Considerations of economy in regard to rock excavation per horse-power developed, led to large quantities of power per wheel; actually, to some 1100 horse-power per wheel in the case of the Paper Company, and to 5000 horse-power per wheel in the case of the Central Power Station. The very idea of a central power station serves, by the way, to meet considerations of economy in rock excavation, by avoiding the necessity of constructing wheel-pits to supply only small powers. When such small blocks of power are wanted, they will be furnished as parts of a larger plant, by transmitted power, as it would not pay to sink a wheel-pit for them alone. We may say, in round figures, that blocks of between 500 and 1000 horse-power will probably, and of less than 500 horse-power will certainly, be furnished on these mill-sites by transmitted power, and the Niagara Falls Power Company is preparing to transmit and distribute such power by electricity.

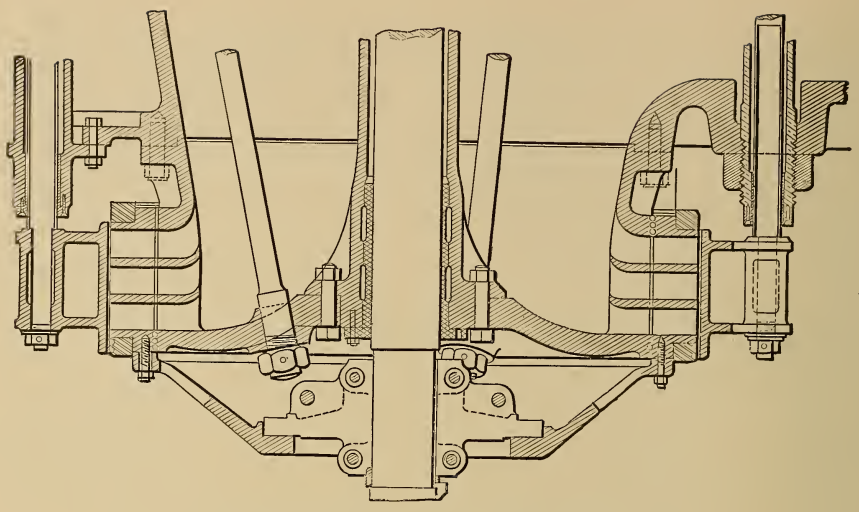
Given, then, turbines with vertical shafts of 5000 horse-power, on about 140 feet of fall, and a prescribed number of revolutions per minute, it follows that American wheel builders are not accustomed, or their shops not fitted, to supply such wheels. The turbine wheel business in the United States is, in point of fact, carried on in a way

entirely different from the way the same business is carried on in Europe. While wheels built to order are the exception in this country, they are all but the invariable rule in Europe ; and, while American builders have, ordinarily, stocks of wheels on hand and turn them out as they would shelf-hardware, wheels built in that way in Europe would there prove entirely unsalable. American wheels are mostly of a complex nature, as regards the action of the water on the buckets of the wheels, and have been perfected in efficiency by test, or, as it has irreverently been called, by the "cut and try" method of procedure. A wheel would be built on the inspiration of the inventor, then tested in a testing flume, changed in a certain part, and retested until no further change in that particular could effect an improvement; another part would then undergo the same process of reaching perfection, and thus, in course of time, the whole wheel would be brought up to the desired high standard of efficiency.

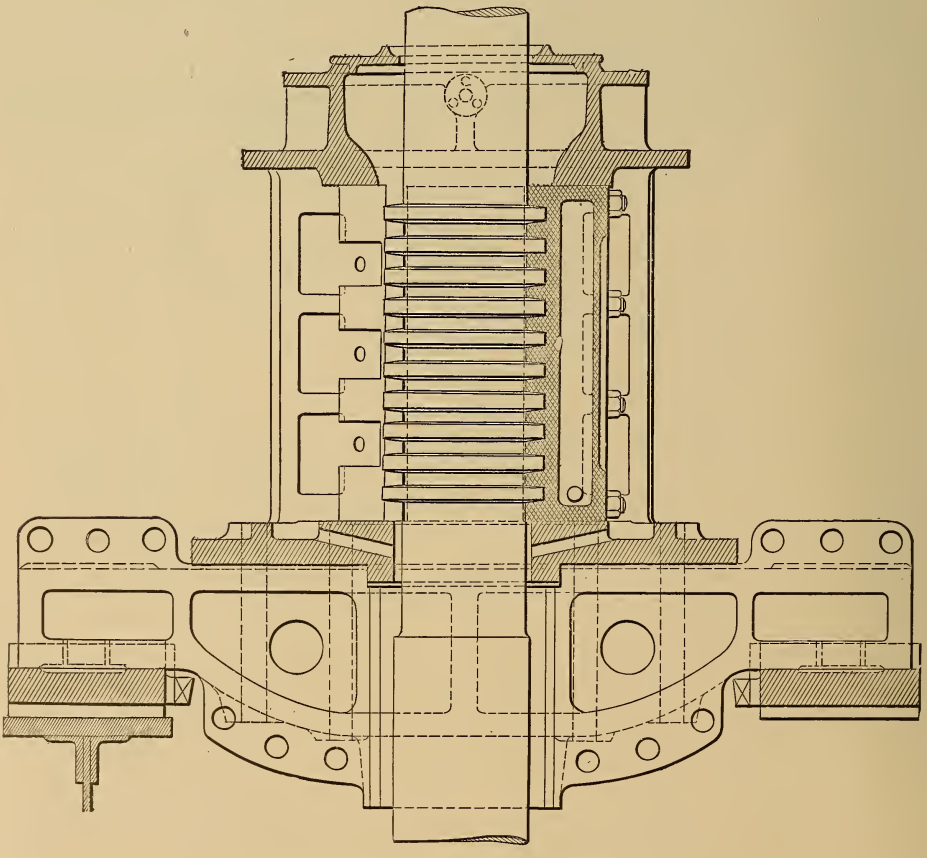
European wheels, on the other hand, are mostly of the standard simple action kinds, and have been perfected mainly by learned computations of forms of guides and buckets. Most American builders also shun high falls, and in their work, turned out in quantity, aim to suit only the ordinary heights of fall. The one special high fall wheel built in the United States, the Pelton wheel, has a horizontal axis. To use it on a vertical axis, and with the multiplicity of nozzles required for producing 5000 horse-power at Niagara, would constitute practically a new wheel. Swiss and other European wheel builders were, therefore, early in the field with designs for producing 5000 horse-power under a 140-foot fall, and having any desired number of revolutions per minute, which with their constant practice in building wheels to order, was, to them, only a case to be met, like most any other. The European designs all appreciated the difficulty of constructing a step, or bearings, that would sustain the great weight of a column of water 140 feet high, added to the weight of the shaft itself, and even of the armature of a dynamo set on top of the shaft. To meet this requirement of construction some designed oil or water bearings along the line of the shafts ; some designed hollow shafts, with an oil bearing on top of a column, ending near the top of the wheel,—the so-called Fontaine step ; others de-



SECTION OF THE TURBINE.



VERTICAL SECTION THROUGH LOWER WHEEL.

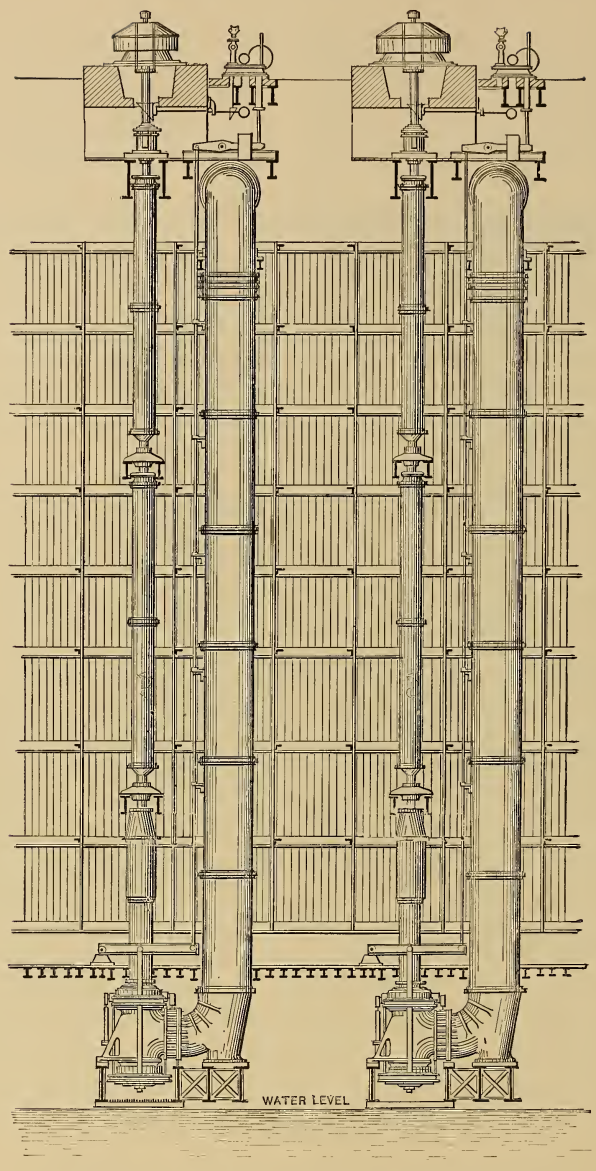


ONE OF THE SHAFT BEARINGS.

signed a water piston bearing; others hit upon the idea of having twin wheels set, the one larger in diameter and vertically over the other, and thus neutralizing the weight of the column of water acting on the wheels; and, finally, we have also a combination of certain of these methods of bearing, safely, the great weight on the revolving parts that support the wheel and the weights upon the shaft.

The wheels themselves, it is agreed among European turbine builders, must be either of the Fourneyron, in America often called Boyden, type, or else Jonval wheels. The 1100 horse-power turbines ordered by the Niagara Falls Paper Company are of the Jonval type, designed and built by R. D. Wood & Co., of Philadelphia, under the direction of the veteran Jonval wheel builder in the United States, Mr. E. Geyelin, and are very much like the Jonval wheels described below as submitted to the Niagara Falls Power Company by Escher, Wyss & Co., of Zurich,

ONE OF THE TURBINE CASTINGS.



GENERAL ELEVATION. FAESCH & PICCARD DESIGN.

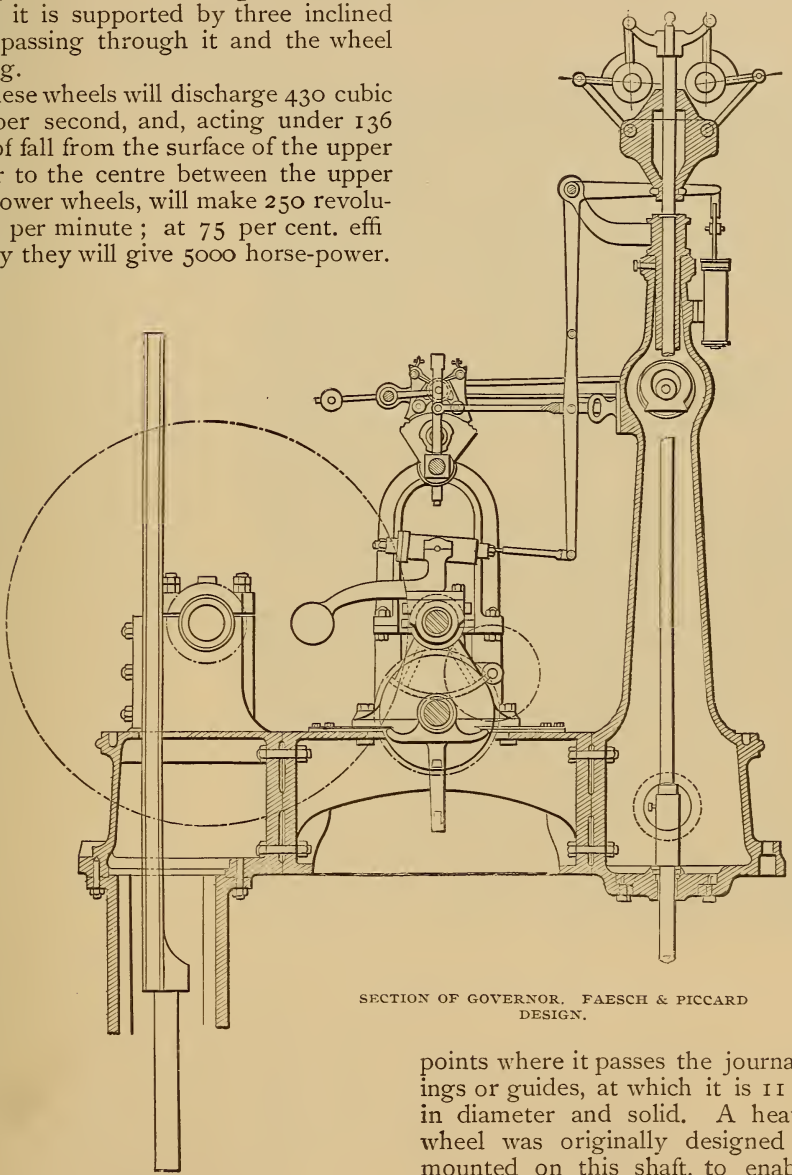
Switzerland, but omitting the upper of the twin wheels.

The three wheels now set and completed for the Niagara Falls Power Company were designed by Faesch & Piccard, of Geneva, Switzerland, and were built under contract with the I. P. Morris Company of Philadelphia. They consist of two Fourneyron turbines, one being set inverted and vertically over the other, so as to neutralize weight on the step or bearing. Each of these twin wheels is, moreover, made three stories high or deep, and the speed-gate consists of a cylindrical rim, moving up and down on the outside of each wheel. To further neutralize weight on the upper bearing of the shaft, the water from the penstock is allowed to pass through the disc of the

upper guide-wheels, and to act vertically upward upon the disc of the upper turbine wheel. The disc of the lower guide-wheel is, on the other hand, solid, and the weight of water upon it is supported by three inclined rods passing through it and the wheel casing.

These wheels will discharge 430 cubic feet per second, and, acting under 136 feet of fall from the surface of the upper water to the centre between the upper and lower wheels, will make 250 revolutions per minute; at 75 per cent. efficiency they will give 5000 horse-power.

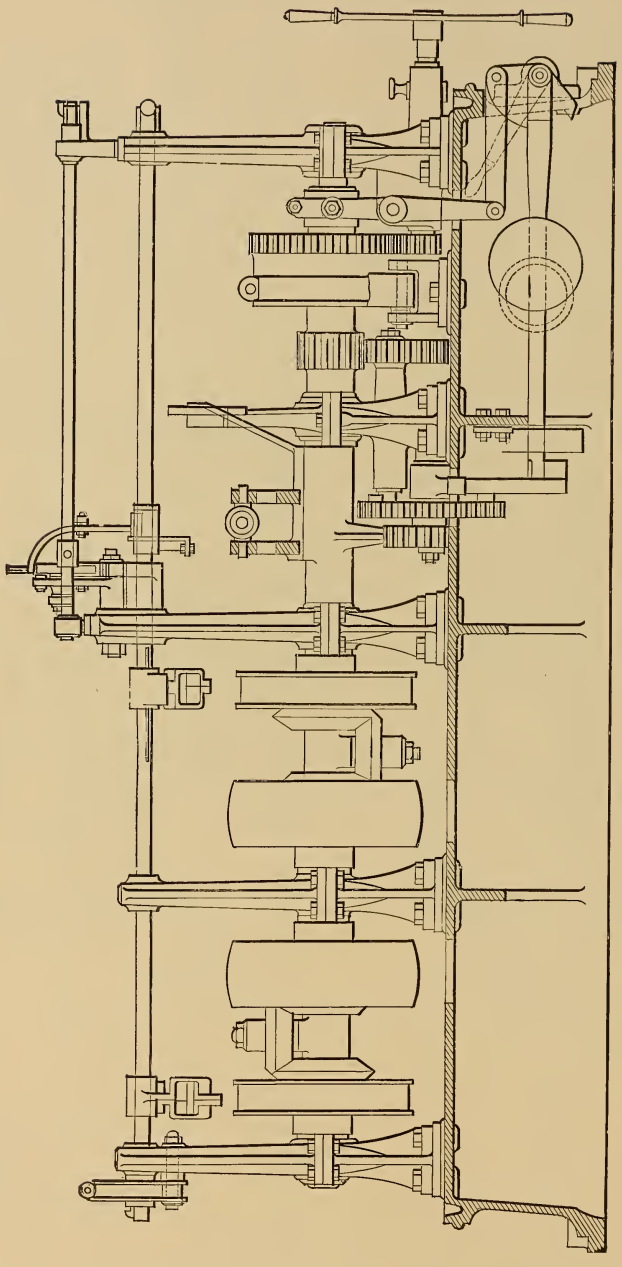
gate. The turbine wheels are made of bronze, the rim and buckets forming a single casting. The shaft is a steel tube, 38 inches in diameter, except at



SECTION OF GOVERNOR. FAESCH & PICCARD DESIGN.

The guide-wheel has 36 buckets; the turbine-wheel, 32. These buckets are thickened in the middle, this being the most approved form of bucket, especially useful when the wheel is acting at part

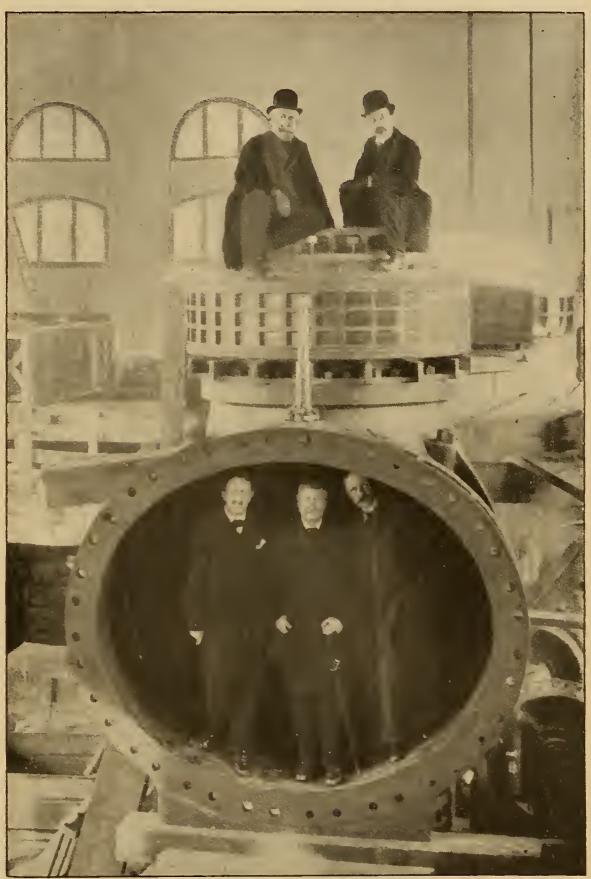
points where it passes the journal bearings or guides, at which it is 11 inches in diameter and solid. A heavy fly-wheel was originally designed to be mounted on this shaft, to enable the governor the better to control the speed of the wheel, but has been replaced by the revolving field of the dynamo. This fly-wheel was to have been 14½ feet in diameter, to have weighed 10 tons, and was to have been



SECTIONAL VIEW OF GOVERNOR. FAESCH & PICCARD DESIGN.

made of forged iron. It was designed for a circumferential speed of 11,400 feet per minute.

The speed-gates of the wheels are plain circular rims, which throttle the discharge on the outside of the wheels. This makes a balanced gate, easy of motion. Together with the governor shown and the fly-wheel, it is warranted by the makers to keep the speed constant within two per cent. under ordinary conditions of operation, and not to allow it to vary more than four per cent. should the work done be suddenly increased or diminished by 25 per cent. To shut the wheel down tight, reliance is had upon the headgates leading to the penstock. At the upper end of the main shaft is a thrust bearing, likewise shown in the drawings, to take up pressure along the shaft, in either direction — upward or downward. This pressure will, naturally, vary with the speed of the wheel, among other causes; hence a thrust bearing, thus operative in either vertical direction, is a necessity. A system of water cooling is provided for this upper thrust bearing.



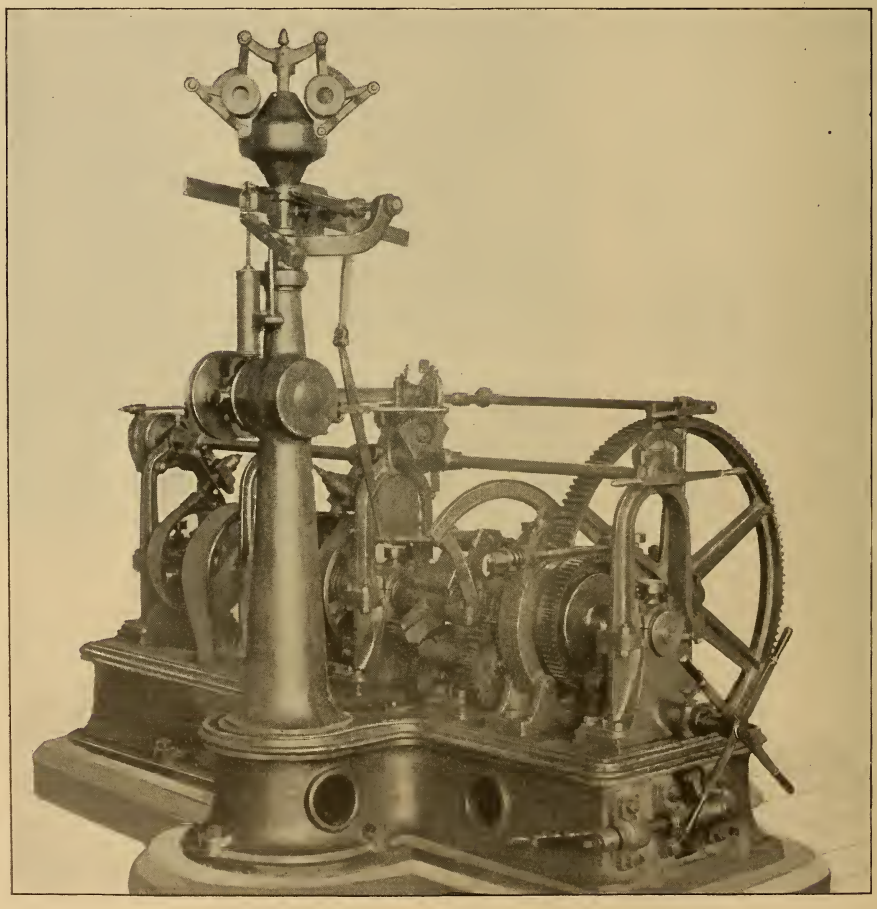
PENSTOCK CONNECTION WITH TURBINE.

The plans of Escher, Wyss & Co. show twin Jonval wheels, but having their discharge from out of the wheel case in a horizontal direction; hence, capable of being governed, and actually governed, by a speed-gate of very much the same construction as that already described in the case of the Faesch & Piccard wheel. There is a post or column passing up through the wheel from the bottom of the wheel case, and an ordinary Fontaine oil-bearing near the upper limit of the case. These wheels, as drawn, are submerged, and they discharge sideways from the slot in which they are to be set, instead of having the tail-race formed at the bottom of the slot and directly under the row of wheels set on beams spanning the slot, as is the case for the turbines now erected. By placing the governor near the level of the water in the tail-race, water from the penstock is obtained under pressure, and the governor can be, and is, designed to be operated by hydraulic power.

In an article by the present writer, prepared several years ago, it was shown that Lowell, Lawrence and Holyoke, Mass., combined, had only one-fifth the horse-power now being developed by

the works of the Niagara Falls Power Company ; that these cities had grown to have a population of about 150,000 people in 45 years, essentially by reason of having some 20,000 horse-power of water-power to keep their inhabitants in employment ; that Niagara Falls is more favorably situated as regards freight rates to the rest of the United States than these cities are ; and that it would, therefore, not be a rash prediction that the now existing (then future) city of Niagara Falls would have a million inhabitants in 50 years. This sentence, the ever active real estate boomer turned to his own uses, though to the discredit of its quoted author, by writing "in a few years," instead of 50 years. But such as it was then written, the author still subscribes to.

With a park on both sides of the river, that has restored and will forever preserve the natural beauties of Niagara Falls to succeeding generations ; with a power development, likewise, on both sides of the river, that has been designed with full regard had to the preservation of all of these wonderful natural beauties ; with constant power delivered at home and to the surrounding country, at rates never before offered so favorable ; the future development of the Buffalo-Niagara Falls district, as a manufacturing centre, no less than as a place of residence, cannot fail to be one of the marvels of the fast approaching twentieth century.



THE FAESCH & PICCARD GOVERNOUR IN PLACE.

L. B. Stillwell

L. B. STILLWELL is the electrical engineer and assistant manager of the Westinghouse Electric and Manufacturing Company, and had under supervision the entire installation of electrical apparatus at Niagara Falls.

ELECTRIC POWER GENERATION AT NIAGARA.

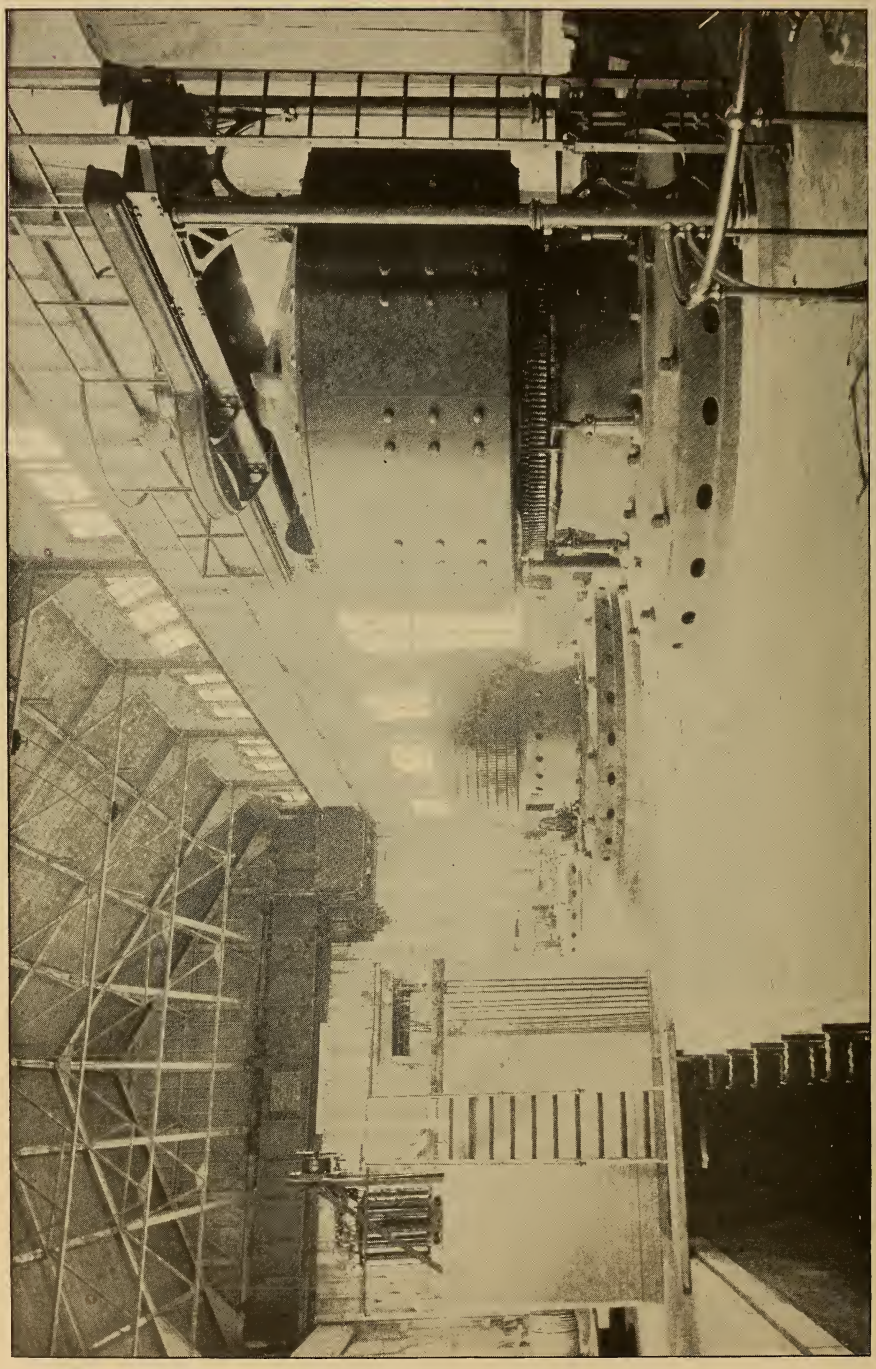
By Lewis Buckley Stillwell, Electrical Engineer.

ELECTRICITY as an agent for transmitting and distributing power has received its most weighty endorsement in its adoption by the Cataract Construction Company, of New York, for their great project at Niagara. No enterprise of modern times, involving special and extraordinary engineering problems, has been more carefully, more patiently, more systematically or more intelligently studied than has the utilization of this, the greatest water power in the world. The officers and directors of the company, controlling financial means ample for their purpose, have, for five years, energetically and persistently endeavored to avail themselves of the best resources of modern engineering science. Confronting a problem without precedent in its magnitude, and almost without parallel in its significance, they have attacked it with energy and ability of the highest order, studied it with keen insight and sound judgment and, in solving it with success, have contributed a chapter of rare interest and meaning to the history of industrial progress.

The utilization of Niagara for industrial purposes imposes upon those undertaking it a responsibility far beyond that which is measured by the capital invested. Science is cosmopolitan; she recognizes no boundary of race or nation; and engineering science of the twentieth century, in passing judgment upon the methods and apparatus employed, while not failing to take into consideration the difficulties and limitations imposed by the boundaries of our present knowledge, will allow no excuse for failure to find out and use the best means known to our age.

It is, therefore, a source of profound gratification that, from the outstart, the policy of the company has been characterized by a breadth of view commensurate with the far-reaching importance of the enterprise. The directors have allowed no local or even national prejudice to bias their judgment. They early threw the lists wide open and in the original competition which they inaugurated, the international commission passed upon no less than twentv-two plans covering practically the whole known range of electric, hydraulic and pneumatic distribution of power, and originating from places as far East as the city of Buda-Pesth, and as far West as San Francisco.

It must be gratifying to Americans that under these conditions a system developed by an American company has been adopted, but for the recent rapid advancement in engineering science which has made this work possible, America is in no position to claim exclusive credit, if she would. In the plans for the hydraulic plant, Switzerland, the land of water powers, shows the way, while in the design of the great electric generators, the most powerful as yet produced, Great Britain is represented directly in the excellent general form of construction adopted, which was proposed by Prof. Geo. Forbes, and indirectly in the work of Hopkinson, Kapp, Thompson, Mordey, and others, whose careful study of the principles underlying the construction of electrical machinery has done much to make it possible to design a machine so far beyond the range of actual experience, in full confidence that the results predicted from theory would



THE INTERIOR OF THE POWER HOUSE, SHOWING ONE GENERATOR COMPLETED.

be realized in practice. Perhaps no country is more largely or more creditably represented in the great Niagara installation than Smiljan Lika, —that sturdy little province on the Adriatic, which has honoured itself by producing Mr. Nicola Telsa, and were it possible to trace to its true source each one of the great number of ideas embodied in the complete installation, it is probable that we should find nearly every civilized nation represented— England, America, Switzerland, France, Germany, Italy, some in greater degree, some in less, but all co-operating to achieve what is, beyond question, one of the most significant triumphs of nineteenth century engineering skill.

The problem in electrical engineering presented by the Cataract Construction Company, as defined by the organization of the hydraulic plant in the power house and the requirements of the proposed market for the power developed, may be stated as follows:

Given, 1st:—Four vertical shafts, direct-driven by turbines making 250 revolutions per minute and capable of delivering at the top of each shaft from 5000 to 5500 mechanical horse-power. Additional turbines and shafts to be installed as the demand for power increases. 2d:—A market for power, beginning just outside the walls of the power house and extending at least twenty miles (and as much further as possible), said power to be used for, (A) general industrial purposes, such as the operation of machinery in mills and factories; (B) the operation of street railways; (C) lighting by arc and incandescent lights; (D) electrolytic purposes; (E) heating.

Required:—The most reliable and efficient method and machinery for utilizing the power for the purposes named.

The system or organization of electric apparatus which was adopted is known as the Tesla Polyphase Alternating-Current System. Each generator delivers alternating current to each of two circuits, the currents in these circuits differing from each other in their time relation, or phase, by 90 degrees; that is to say, the current delivered to each circuit attains its maximum value at the instant when the current delivered to the other circuit is zero. The frequency is 25 cycles per second,—in other words, the direction of the current is reversed 3000 times per minute. By means of rheostats, controlling the field circuits of the generators, the potential of the current delivered is adjustable up to the limit of 2400 effective volts. In ordinary service, and until transmission over great distances is undertaken, the normal potential will approximate 2100 volts, but, to compensate for the losses incident to long distance transmission, the generators may be operated at any potential not exceeding 2400 volts.

The currents delivered by the generators are conveyed through heavily insulated cables to the switchboard. There, by means of suitable switching devices, the engineer in charge of the station may, at will, connect any one of the generators, or any combination of the generators, to the external circuits which convey the currents from the power house to the consumers. These external circuits, known as feeder or supply circuits, passing from the switchboard, are supported upon iron brackets in a brick-lined subway within the power house, as shown in the illustration on page 286. Insulated, lead-covered cables are used, and these, leaving the subway, are continued through the bridge connecting the power house with the transformer house on the east bank of the power canal. The cables conveying current, intended for the use of tenants of the company and other consumers of power within a radius of 2 or 3 miles of the power house, pass directly through the transformer house and enter a conduit leading to the works of those tenants who are, at present, the principal users of the power.

Current intended for transmission to considerable distances, as, for example, to Buffalo, will pass from the switchboard through similar lead-covered cables in the power house subway and the bridge to the transformer house. There it will enter the "step-up" transformers, and from these current at high potential (E. G. 20,000 volts) will

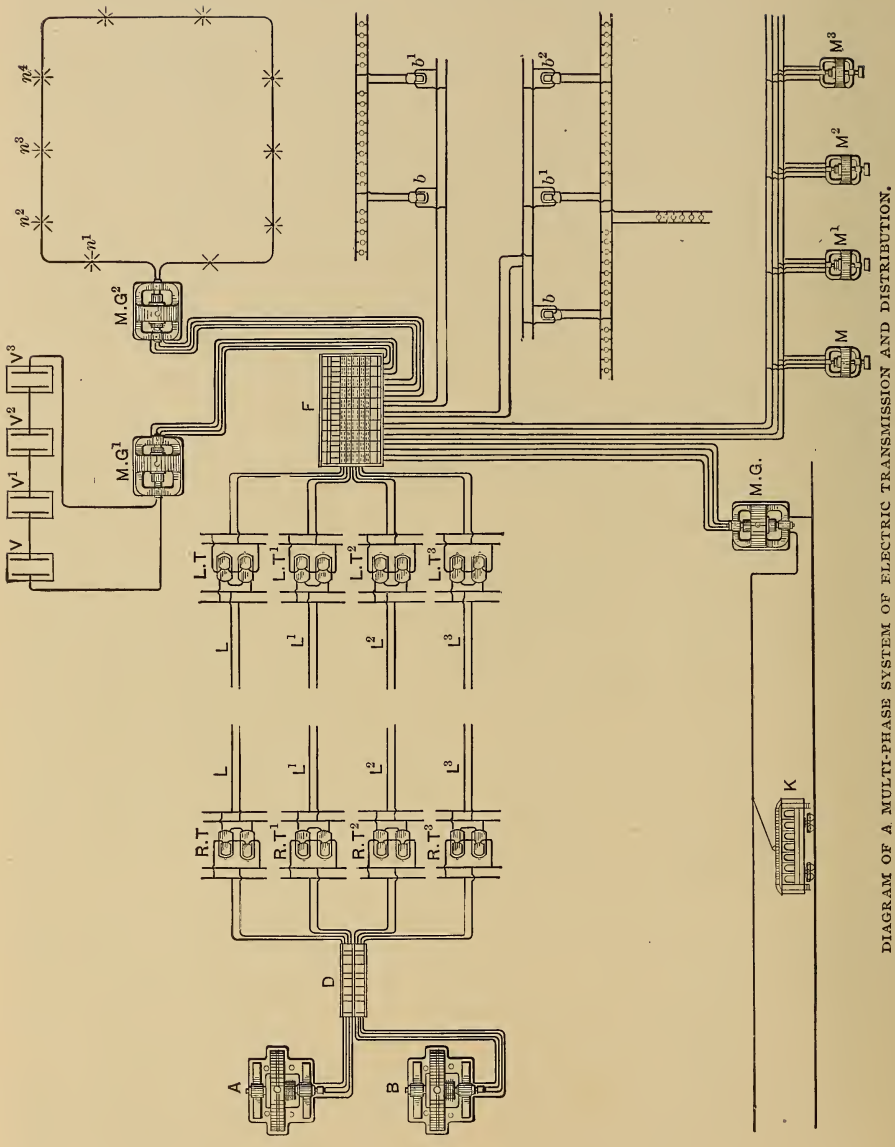


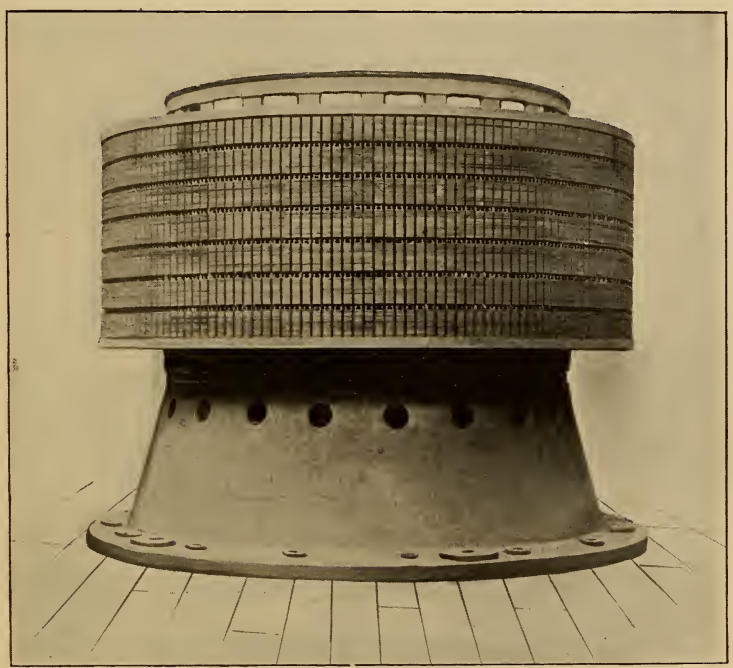
DIAGRAM OF A MULTI-PHASE SYSTEM OF ELECTRIC TRANSMISSION AND DISTRIBUTION.

be delivered to the long-distance transmitting circuits. It has not yet been determined whether these long-distance circuits shall be overhead or underground. At the distant end of the circuits "step-down" transformers will be employed to reduce the potential of the currents to an amount suitable for local distribution.

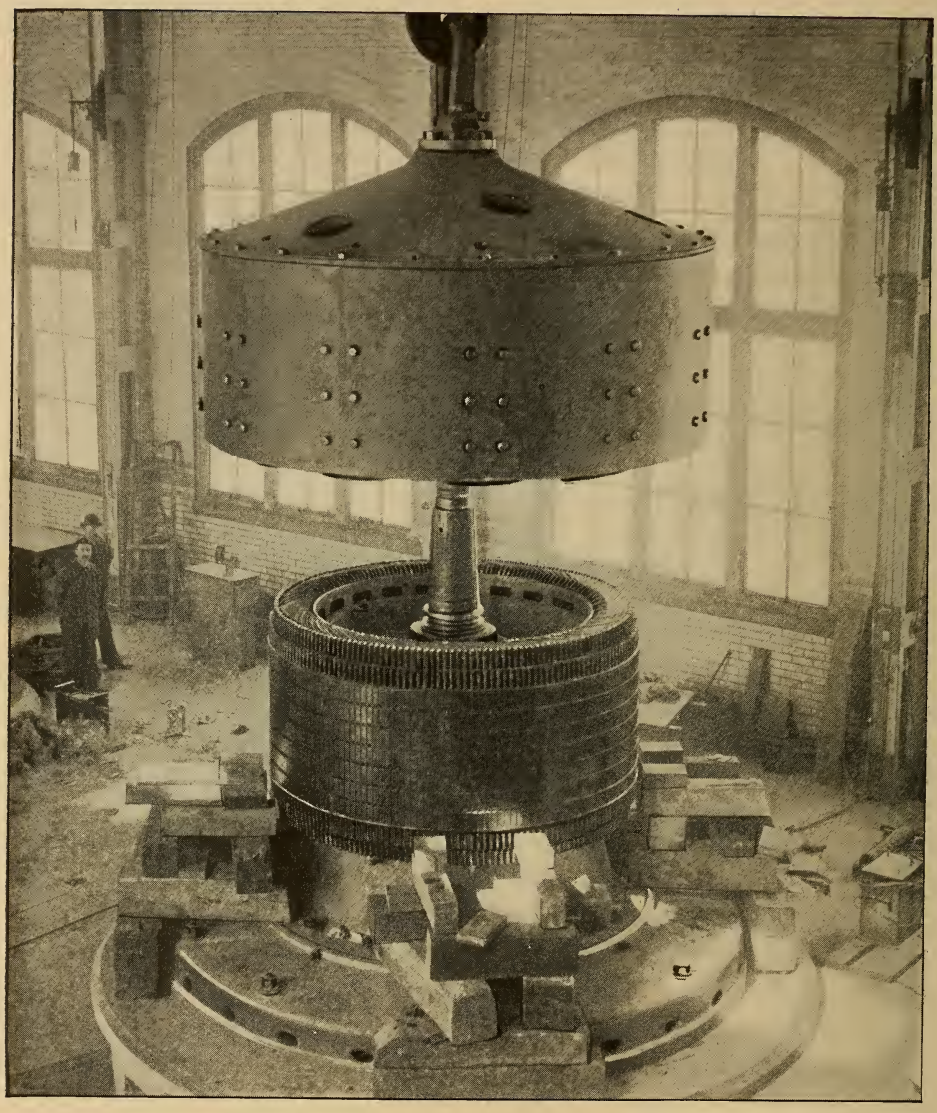
The kind and amount of apparatus which it will be necessary to install upon the premises of the users of power depends upon the kind of service required. In the case of large motors, the current delivered by the local distributing circuits at Niagara may be supplied to the machines without reduction of potential by transformers. In the case of smaller motors, and in the case of commutating machines used to supply direct current, step-down transformers will ordinarily be employed. The general organization of the system and character of the apparatus required for each of the principal types of service are illustrated in the diagram on the opposite page.

Referring to this diagram, each of the generators A and B delivers two separate and distinct alternating currents to the step-up or raising transformers RT, RT^1, RT^2, and RT^3, through the switchboard D. The current, delivered by the generators at 2000 volts, is transformed by the raising transformers to a high potential suitable to long-distance transmission, say 20,000 volts, and is delivered by them to the transmission circuits L, L^1, L^2, and L^3. At a point conveniently located with reference to the district where lights and motors are to be supplied a sub-station is erected. The transmission circuits enter the station and deliver their currents to the step-down or lowering transformers LT, LT^1, LT^2, and LT^3, which, in turn, deliver currents at moderate potentials, suitable for local distribution.

The switchboard F affords means whereby the circuits coming from the various groups of lowering transformers may be readily transferred and inter-



ONE OF THE 5000 HORSE-POWER ARMATURES.



A FIELD RING READY TO BE LOWERED ON A GENERATOR SHAFT.

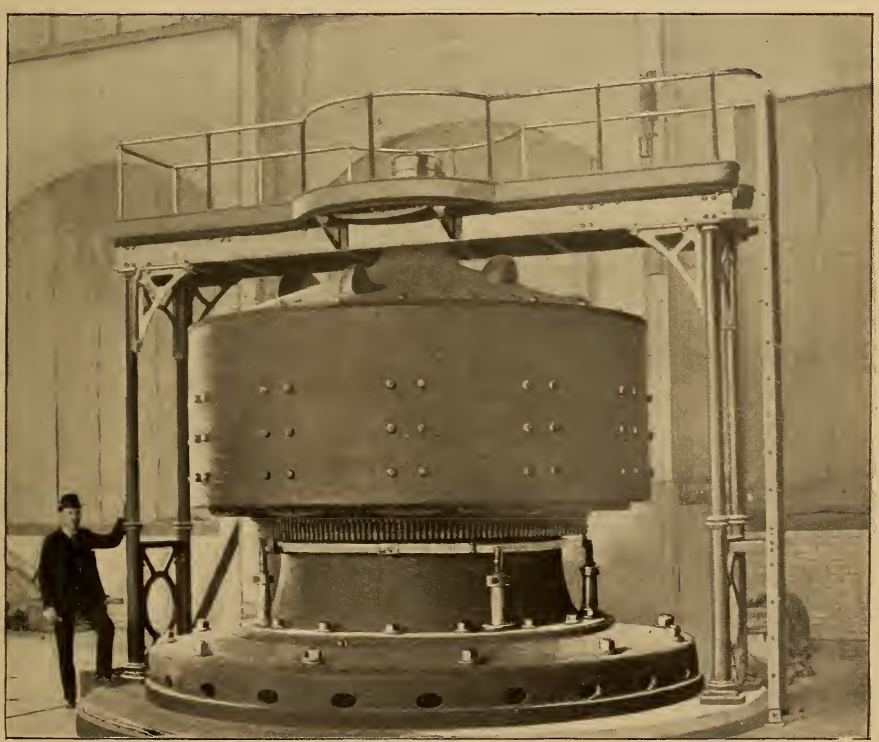
changed, so that any of the transmission circuits may be used to supply any of the local distributing circuits, as may be advantageous or convenient, or all of the local circuits may be supplied with current from bus bars to which the transmission circuits of like phase are connected in parallel.

In the diagram, beginning at the left of the switchboard, the first four-wire circuit is used to supply alternating current to the motor-generator or rotary transformer MG, which, in turn, delivers direct current at 500 volts to a trolley line, from which the street car K is supplied. The second circuit supplies the motors M, M^1, M^2, and M^3 of the two-phase, synchronous type, or of the induction type, which are adapted to general power purposes in mills, fac-

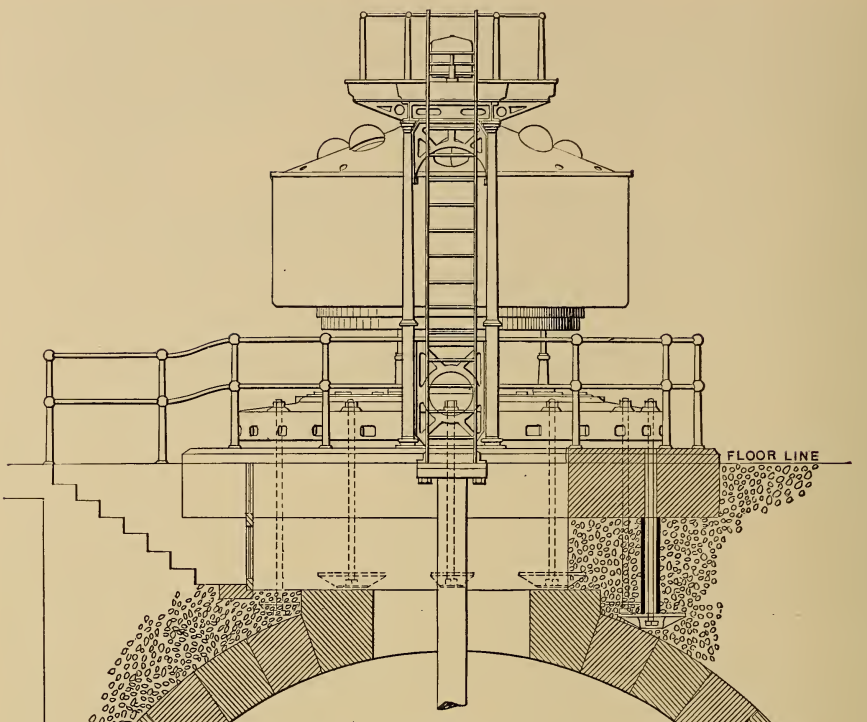
tories, etc. The next four-wire circuit is divided into two two-wire circuits, and is used to supply incandescent lamps through the transformers b, b^1, and b^2. The next circuit supplies alternating current to the motor-generator MG^2, which delivers direct current for arc lighting purposes. The last circuit shown supplies the motor-generator MG^1, which, in turn, delivers direct current at a low potential for electrolytic purposes, as indicated in the vats V, V^1, V^2, and V^3.

It is not intended to attempt the supply of incandescent lights in general in the manner indicated in the diagram, as the frequency is rather low for that purpose. At 25 cycles per second a slight wavering or variation in the intensity of the light is perceptible under certain conditions in the case of lamps having especially thin filaments, such as a 10 candle-power lamp for a 100-volt circuit. In 100-volt lamps of greater candle-power, and in 50-volt lamps, the light is entirely satisfactory. Arc lighting can, of course, be accomplished not only in the way shown in the diagram, but also by the indirect method of employing polyphase motors to drive arc light machines of the types generally in use.

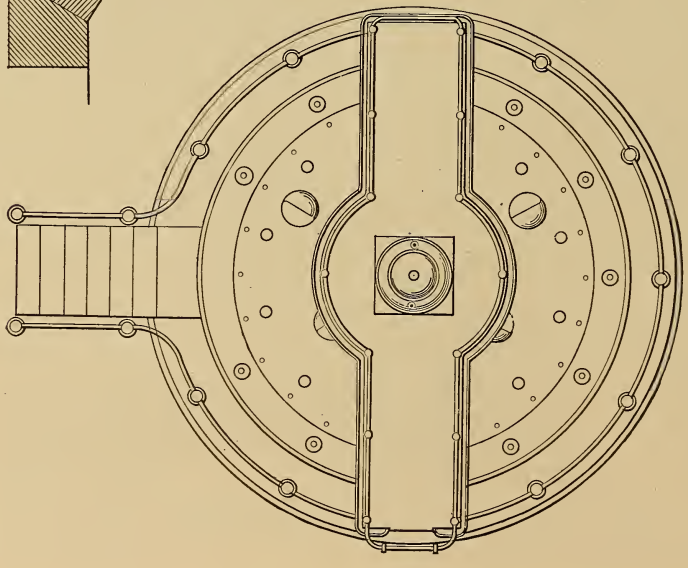
The frequency selected is in every respect admirable for power purposes, and was chosen in preference to a higher frequency because the amount of energy required for lighting from Niagara will, for many years, and perhaps for all time, constitute but a comparatively small part of the energy distributed. At present the only practicable way to utilize Niagara power for lighting purposes is by substituting motors for the engines now used in arc and incandescent lighting plants in Niagara, Tonawanda, Buffalo and other cities and towns to which the circuits may be extended. When the demand for



THE FIRST GENERATOR IN POSITION IN THE POWER HOUSE AT NIAGARA.



SIDE ELEVATION OF ONE OF THE GENERATORS.

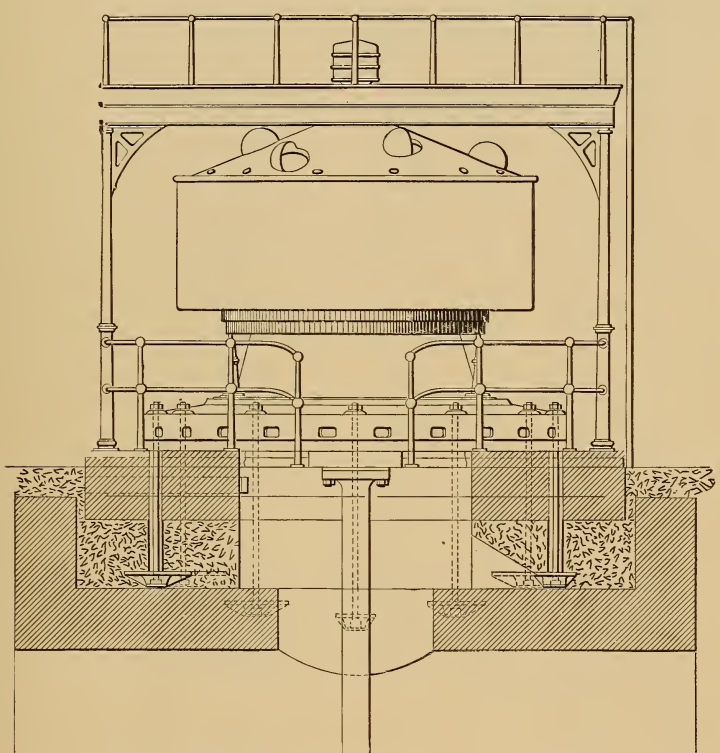


A TOP VIEW.

current to be used for lighting purposes becomes sufficiently important to justify a change in the apparatus, and, perhaps, in the methods now employed for lighting the cities and towns to which the circuits may be extended, a certain number of generators of higher frequency may be installed.

The drawings reproduced on this and the opposite pages are front and side elevations and a plan, showing the relation of the generator, the bed space occupied by the generators, with the actual size of the machine as shown on page 258.

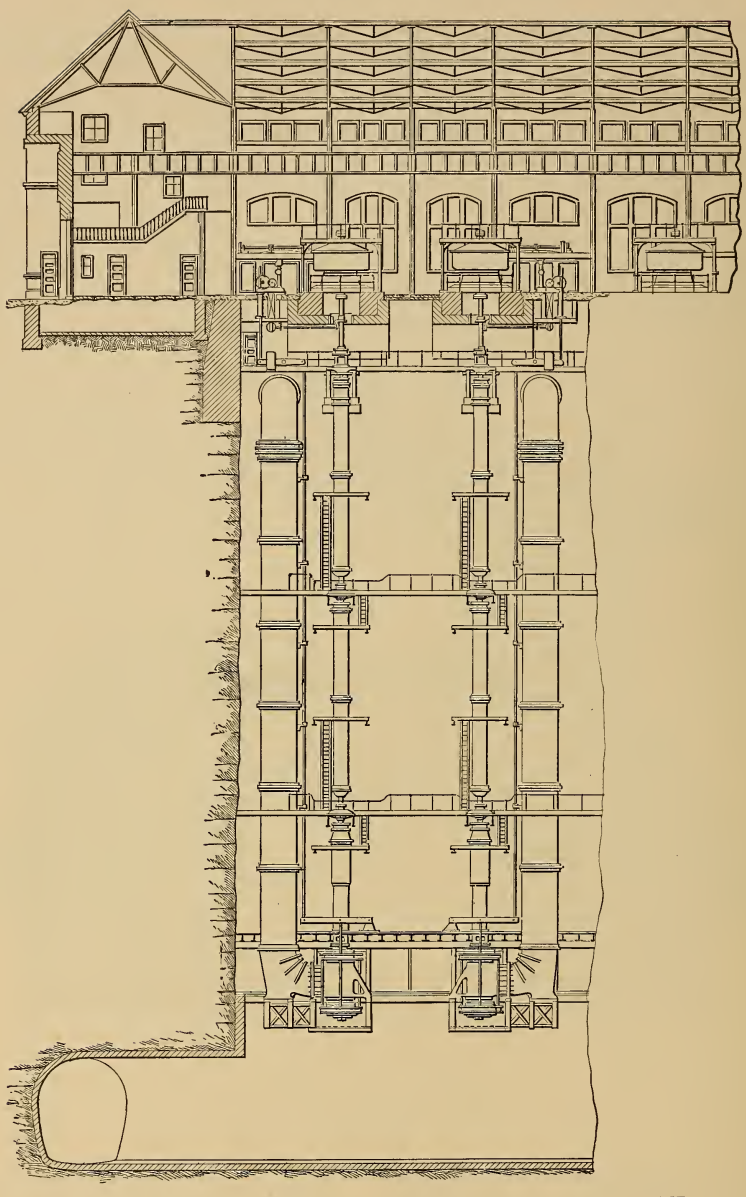
The height of each generator from the bottom of the bedplate to the top of the floor of the bridge is 11 ft. 6 in. The diameter of the bedplate is 14 ft., and the outside diameter of the revolving field ring is 11 ft. 7⅛ in. Each generator delivers 5000 electrical horsepower, and requires about 5150 horsepower delivered through the turbine



FRONT ELEVATION AND SECTION THROUGH FOUNDATION.

of concrete supporting the massive capstone and the excellently constructed arch which spans the wheel pit. On pages 262 and 263 sections through the power house and wheel pit, reproduced from the general drawings, show the generators in relation to the power house, the wheel pit and the hydraulic plant. The large scale upon which the work has been planned and carried out is graphically evident upon comparison of these sections, illustrating the relatively small shaft to drive it under full load. Exclusive of the bridge, which is simply used to give access to the brushes bearing upon the collecting rings at the top of the shaft, the entire machine could be placed in a room 15 ft. square and 15 ft. high.

The weight of each generator is 170,000 lbs., of which about 79,000 lbs. are in the revolving element, which is made up of the shaft, the driver to which the field ring is attached, the



PARTIAL LONGITUDINAL SECTION OF THE POWER HOUSE AND WHEELPIT.

field ring with its pole pieces and bobbins, and the collecting rings, carried upon an extension of the shaft above the driver. The speed at which the field revolves is normally 250 revolutions per minute, and the fly-wheel effect of the revolving parts of the machine, measured by the pounds multiplied by feet per second squared, is 1,274,000,000.

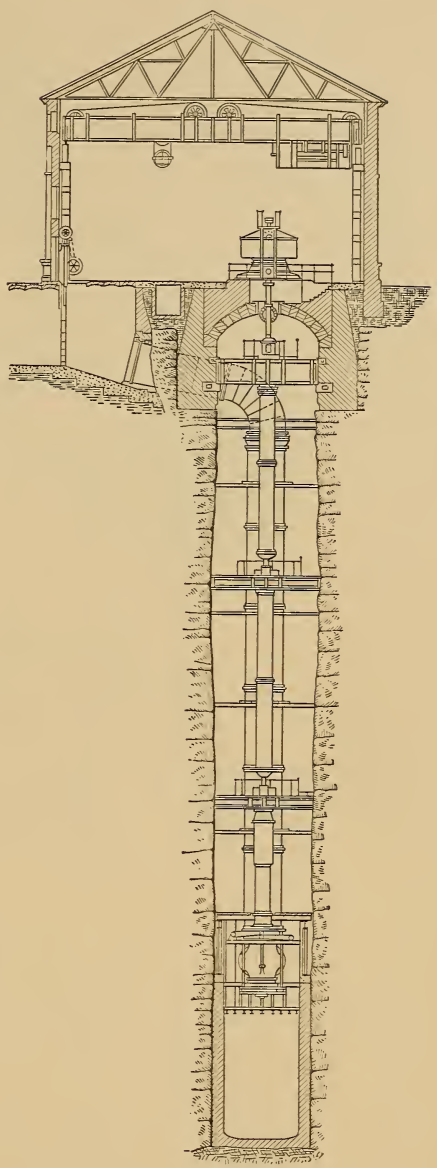
The conditions to be met in the construction of the generators, as determined by the plans adopted for the hydraulic plant, were such as to impose very considerable difficulty upon the designers and manufacturers. These conditions were, in brief, an output of 5000 electrical horse-power, a speed of 250 revolutions per minute, a weight in

the revolving element of the machine not exceeding 80,000 lbs., and a fly-wheel effect of the revolving parts, measured by the pounds multiplied by feet per second squared, of not less than 1,100,000,000.

In saying that the imposition of these conditions involved difficulties, no reflection upon the wisdom of the decision which imposed these conditions is intended. It would be, perhaps, more exact to say that the general specifications laid down were such as called for the highest skill in the designers and builders of the generators. The conditions have been met successfully, and the object which the officers of the Cataract Construction Company had in view is attained. The Niagara generators represent to-day the highest state of the art of design and construction of electrical machinery.

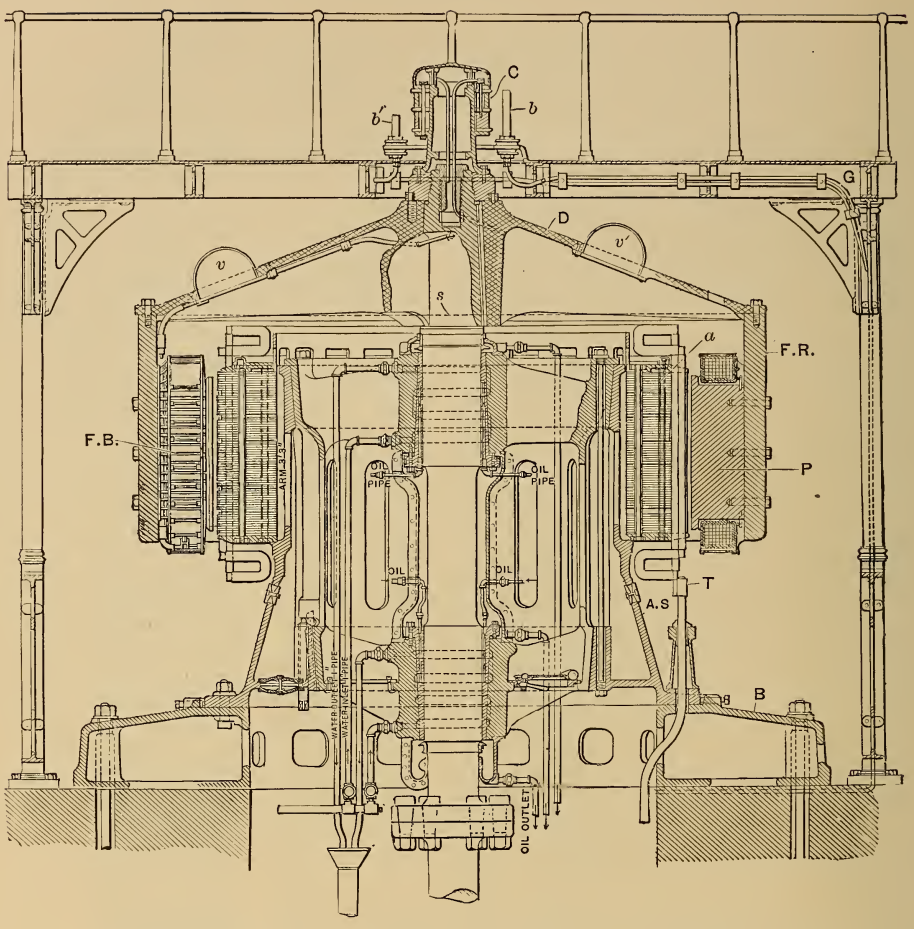
The construction of the generators is illustrated by the reproductions from the general drawings on pages 264 and 265. In the vertical section through the centre line of the shaft on page 264, *a* represents the stationary armature, secured in place by the armature support AS, which, in turn, rests upon the bedplate B. One of the four terminals at which the current from the armature is delivered to the cables leading to the switchboard, is shown at T. Of course, since the armature is stationary, no ring collectors or brushes are needed. The revolving part of the generator consists of the shaft S, carrying the driver D, the field ring FR, the steel pole pieces P, the field bobbins FB (each bobbin surrounding a pole piece), and the collector C, by means of which the current delivered from the exciters to the brush holders *b*, *b'*, is conveyed to the field bobbins. In the horizontal section through the armature and field, *a* is the armature, FR the field ring, P, P', etc., are the pole pieces and B, B', etc., the field bobbins. The clearance between the armature and the field poles is one inch.

The power house is equipped with a 50-ton electric crane, built by Messrs. Wm. Sellers & Co., of Philadelphia, which is of ample strength to handle



CROSS SECTION OF POWER HOUSE AND WHEELPIT.

any part of the electric or hydraulic machinery, and by means of this the revolving parts of the machines may be removed when necessary. In doing this the collecting rings near the top of the shaft are first removed, and the bridge is taken out of the way. The key which fixes the driver to the shaft is then withdrawn, and a special tool,



VERTICAL SECTION OF ONE OF THE 5000 HORSE-POWER GENERATORS.

which may be described as a combined eyebolt and hydraulic pump, is attached to the driver by eight heavy tap bolts. The pressure pump is then operated by hand, and, leakage of water being prevented by packing rings, a pressure of many thousand pounds, tending to lift the driver with reference to the shaft, is exerted. In this way the driver is loosened from the shaft, and, with the field, is then raised bodily by the electric crane. The bearings and the castings which support them are next lifted out, and the shaft is removed if necessary. When this has been accomplished, a clear space is left within the fixed part of the machine, that is, within the armature support, five feet in diameter, through which parts of the turbine shaft or other machinery from the wheel pit can be raised.

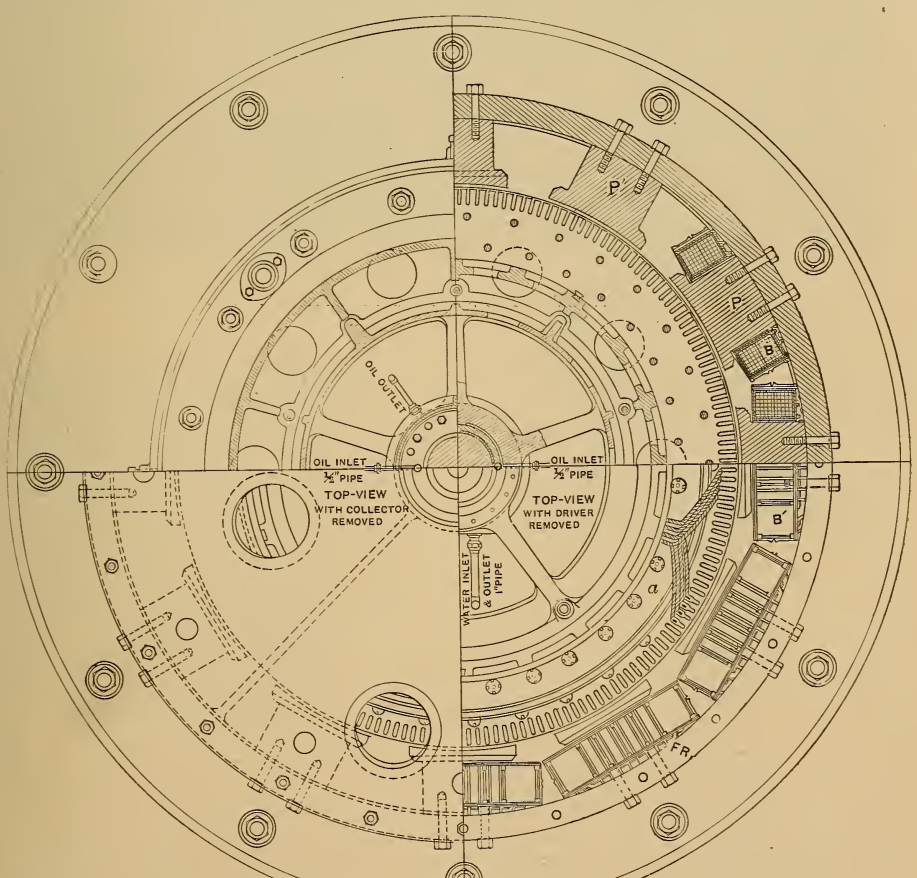
An attractive feature of the form of construction adopted is the fact that the magnetic attraction between the field poles and the armature acts against the centrifugal force. As compared with the centrifugal force at high speeds at which the ring must still be safe, the magnetic attraction is not very great, and, unless the field is charged, there is, of course, no magnetic pull between armature and field. But with normal conditions, this attraction tends to reduce the strains in the ring, due to centrifugal force, whereas, were the armature revolved inside of the field,

the magnetic pull would be added to the centrifugal force.

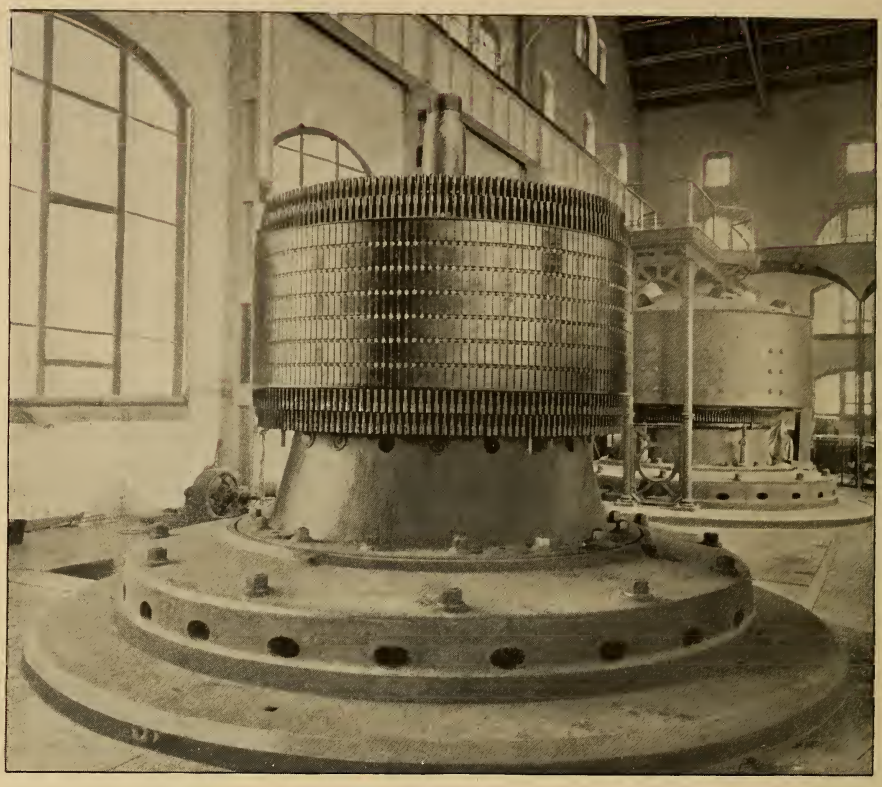
The armature and field are ventilated by means of openings in the driver, provided with special ventilators *v*, *v'*, so arranged as to draw air up through the machine, and throw it out at the top. A considerable draught is necessary, since, at full load, heat equivalent to about 100 horse-power, representing the loss in the generator due to magnetization of the iron and the resistance encountered by the currents traversing the conductors, must be dissipated.

The sections on pages 260 and 261 show the method of securing the bed plate in place. Eight 2½-inch bolts are used, and, at their lower ends, are securely held by castings buried in the concrete foundation. The masonry is of the highest class, massive blocks of Queenston limestone being used for the capstone and in the construction of the arch. In the latter a cylindrical steel casting takes the place of the keystone, the turbine shaft passing through it to the dynamo shaft above.

The armature support is a single casting of cylindrical form, and is securely bolted to the bedplate, upon which it is adjusted by set screws in a flange around the circular bed, and is afterwards babbitted to secure rigidity. This cylindrical casting has on its outer periphery a series of vertical ribs, which terminate at the lower ends in a flange upon which the armature ring rests. The latter was lowered to this flange



HORIZONTAL SECTION.



THE ARMATURE OF THE SECOND GENERATOR IN PLACE.

while heated, and then shrunk into place against the ribs on the cylindrical support. Five of these ribs are provided with dove-tailed keyways, corresponding with keyways in the armature ring. Into these, after the ring was shrunk into place, metal keys were cast. While the outer surface of this casting which supports the armature is cylindrical, its inner surfaces, at the top and bottom, form sections of two truncated cones into which fits and is securely bolted a second casting carrying two massive, five-arm spiders, which support the upper and lower bearings. The illustration on page 267 shows the armature support and armature core after the latter has been shrunk into place. The vertical slots which will be noted around the periphery of the core, are ready for the reception of the armature conductors.

The construction of the casting which carries the spiders supporting the bearings is illustrated on the same page. The end view shows the bushings in place, and these bushings are separately illustrated on page 268. The bearings, which are of the best quality of bearing metal, are in two parts, are fitted into conical bearings of iron surrounding the shaft, and are provided with set screws to assist in withdrawing or tightening when necessary. The bearings are lubricated by oil under pressure, admitted at a point midway between the top and bottom, and also at a point near the top.

Grooves are cast in the hub of each spider, with pipes at each end, permitting the circulation of water to cool the bearings, this water being conveyed to the bearings direct from the city mains at a pressure of 60 pounds per square inch. The oil is supplied from a reservoir placed at an elevation of about 30

ft. above the upper bearing. After having passed through the bearings, it is filtered and pumped back into the reservoir. The pressure at which it is supplied to the machine is that due to gravity.

THE ARMATURE SUPPORT AND CORE.

The illustrations on pages 269 and 266 show, respectively, the armature core, or ring, in place upon its support before winding, and the armature complete, with conductors in the grooves or slots around the periphery of the core. The armature core is built up of

SIDE VIEW OF CASTING CARRYING SPIDER FOR BEARINGS.

thin sheets of mild steel, No. 30 B. W., G., and, to secure free circulation of air, is divided horizontally into six equal parts, separated from one another by one-inch spaces. Each layer of the core consists of eleven segments, which are so placed that all joints in each layer are overlapped by the segments of the adjacent layers. One of the sheets of steel is shown on page 268. These pieces are punched out of large sheets of a certain predetermined quality, .015 of an inch thick, by steel dies in powerful presses. They are afterwards thoroughly annealed. In this process of annealing, the surfaces of the segments are oxidized, the oxide serving as insulation to reduce the eddy currents which are set up in the iron of the armature when the machine is in operation.

The ring thus built up is securely held together by sixty-six bolts of nickel steel, containing a high percentage of nickel which renders them practically non-magnetic. These bolts are, of course, carefully insulated from the core. The large discs, or end-plates, at the top and bottom of the armature ring are of brass. At the time of tightening the bolts, the steel plates are pressed closely together by

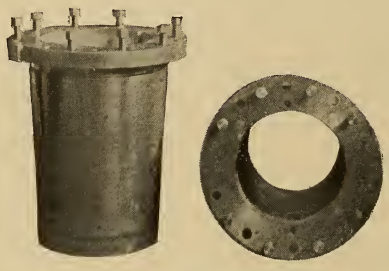
END VIEW OF THE CASTING.

powerful hand-presses. The six equal parts, or layers, into which the core of the armature is divided, are separated from one another by segments of cast brass, these segments being cast in such form that, while they have sufficient strength to withstand the pressure under which the armature core is assembled, the larger part of the spaces between the six adjacent rings or steel plates is left open for the circulation of air.

The armature ring, when finally

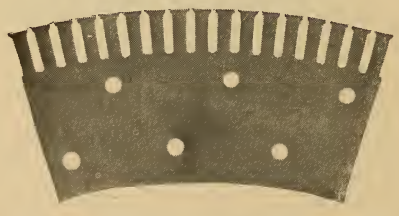
built up, is turned on the inner surface so as to accurately fit the ribs of the armature support. It is then heated, and lowered into place against the flange on the support, and, in cooling, shrinks itself tightly into place against the ribs.

The armature conductors consist of copper bars $1\frac{11}{32}$ in. by $\frac{7}{16}$ in. in section, the edges of the bars being rounded to a radius of about one-eighth of an inch to avoid cutting the insulation. Two of these bars, after being insulated, are placed in each of the 187 slots around the periphery of the armature core. The conductivity of the bars used is above 100 per cent., by



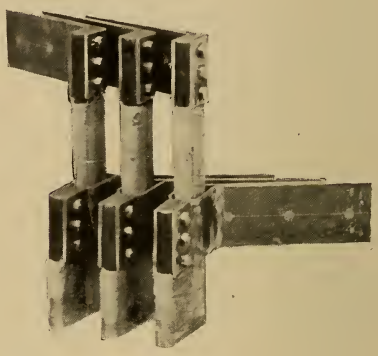
DETAILS OF ARMATURE BEARINGS.

Matthiesen's standard. In the case of the second generator the conductivity of the copper, furnished by the Washburn & Moen Mfg. Co., of Worcester, Mass., is 102.6 per cent., which strikingly illustrates the fact that what was considered pure copper when the standard referred to, and still generally used,



ONE OF THE SHEETS MAKING UP THE ARMATURE CORE.

was determined, is now inferior to certain grades of commercial copper. The proper insulation of these conductors is a matter of the greatest importance. Each conductor must be separated from its neighbors and from the iron of the armature core by insulating material which is abundantly able to withstand the potential to which it will be subjected, and in order to be sure of this, a large factor of safety is allowed; that is, the insulation is tested by apply-



JUNCTION OF ARMATURE BARS AND CONNECTORS BEFORE SOLDERING AND INSULATING.

ing a potential several times as great as any to which it will be subjected in service.

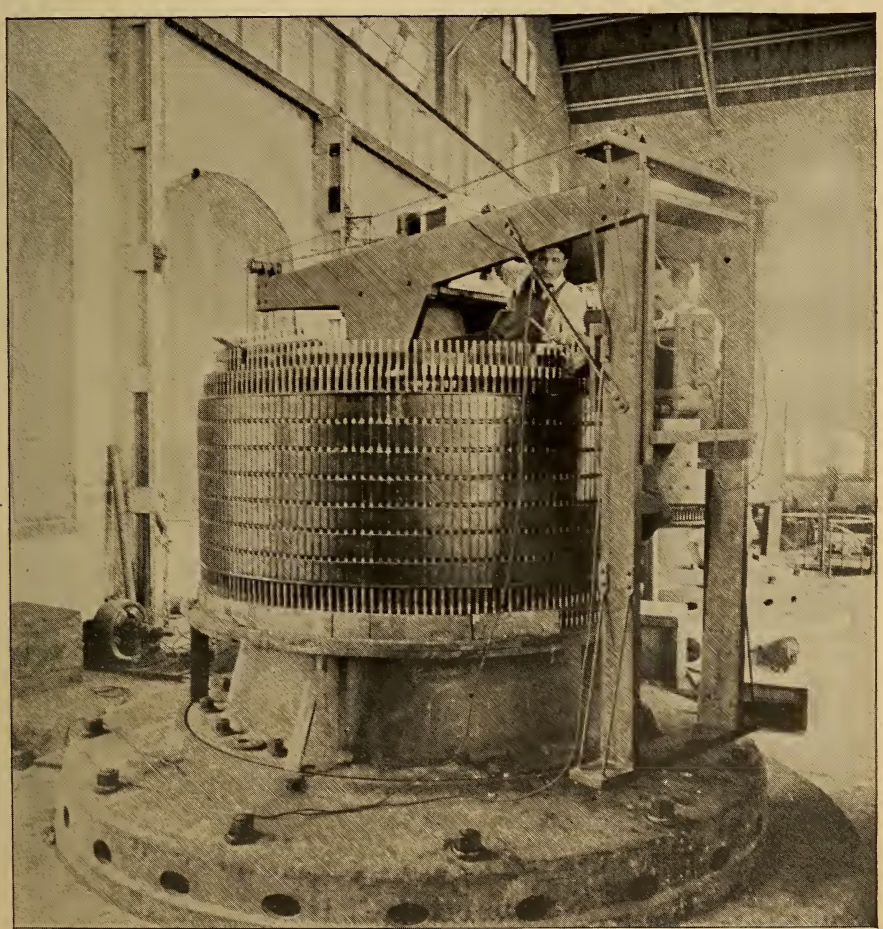
At the factory, the insulation of each bar was tested by applying a potential of 15,000 volts. One terminal of the transformer used in testing was connected to the conductor, and the other terminal was connected to a layer of tinfoil, wrapped about the outside of the insulation. During the erection of the generators at Niagara, the insulation was again tested by applying a potential of 6000 volts, one terminal of the testing transformer being connected to the conductors, while the other was connected to the armature core. An alternating potential was used in both tests, and the values given are in each case the mean or effective potential.

The material used for insulating the bars is principally mica. The armature conductors project above and below the core, as shown in the illustration on page 269, and connections are made by pieces of copper, punched from large sheets and shaped into proper form by presses and iron moulds. These connectors are insulated by mica and rubber insulating tape, the former being used only where connectors conveying

currents of considerable difference of potential are adjacent to each other.

It is very important that good electrical connection be made at the junction of connector and armature bar. The illustration on page 268 illustrates the connection before the solder is applied. Three holes drilled through the split end of the connector correspond to three holes in the end of the armature bar. The split end of the connector is fitted closely to the end of the bar, and when the holes in the connector and bar are properly aligned they are securely fixed in place by three wrought iron bolts, the holes through one side of the connector being reamed out to receive the heads of the bolts. After the nuts are tightened into place, the projecting ends of the bolts are upset; that is to say, they are split and, as it were, riveted to lock the nuts.

The joint is then thoroughly soldered, this work being greatly facilitated by the use of an electrical soldering tool. The process will be best understood by referring to the illustration on this page, which was taken during the erection of the first generator. A transformer, supplied with alternating current at a potential of about 150 volts, is so wound as to deliver a current of very large quantity but low pressure. This current is coveyed through heavy jaws, or terminals, of copper to the point of junction between the armature bar and

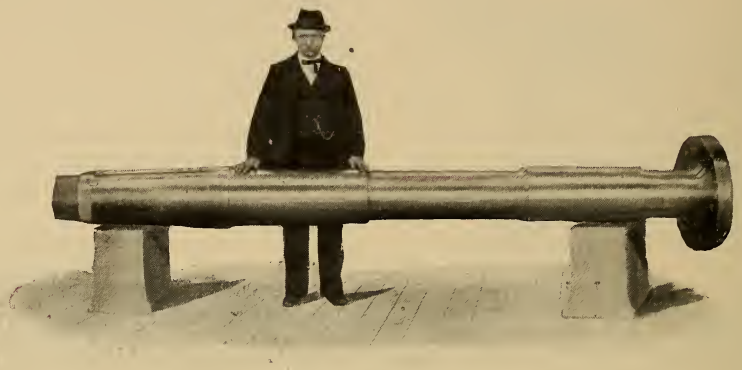


ELECTRICALLY SOLDERING THE CONNECTIONS OF AN ARMATURE WINDING.

its connector, and in a few seconds this point is heated to a high temperature. The joint is then readily flooded with solder. This is afterwards dressed up by a file, and the joint is thoroughly insulated.

In the illustration the soldering transformer and one of the operatives are seen carried at one end of an oak frame, supported upon the shaft of the generator and counter-weighted at its opposite end. In soldering the connections the operative slowly revolves the frame about the armature. The seat which carries him is adjustable, so that the connections at the bottom of the armature, as well as at the top, can be reached, and it is provided with rails upon which the transformer is pushed forward until the copper jaws grasp the connection, or withdrawn after the soldering is completed.

When the armature is completely wound, as shown in the illustration on page 266, the conductors are so connected as to form two complete circuits, each thoroughly insulated from the other and from the steel core, and so related to each other that the electromotive forces induced in them by the revolving magnetic field are ninety degrees apart.



THE GENERATOR SHAFT.

Coming now to the revolving parts of the generator, we begin with the shaft, which is shown on this page. It is of open-hearth steel, and was forged and rough-turned by the Cleveland City Forge and Iron Company of Cleveland, Ohio. The diameter of the shaft in the bearings is $12\frac{15}{16}$ in. It is tapered at the upper end to receive the driver, and a flange, 27 in. in diameter, is forged at the lower end to provide means for connection to the flange at the top of the turbine shaft. These flanges are bolted together by eight tapered steel bolts. At its extreme upper end the shaft is threaded to provide means for securing

THE DRIVER FOR THE FIELD RING.

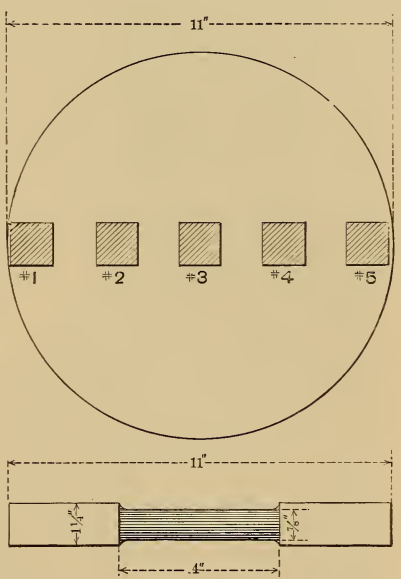
in place the revolving parts which project above the driver and carry the collecting rings.

For the purpose of securing information as to the physical properties of the steel used for the shaft, it was originally forged of extra length ; an end, several inches in length, was then cut off, and from this five samples were taken, two being cut from the periphery of the shaft at opposite ends of a diameter; one, from the centre of the shaft; and two, from points midway between the periphery and the centre, as illustrated in the cut on this page, where the numbers 1, 2, 3, 4 and 5 indicate the places in the section of the shaft from which the test samples were taken. These samples were tested by the Pittsburgh Testing Laboratory at Pittsburgh, and the fact that forged shafts are stronger near their outer surface than elsewhere is shown in an interesting manner by the results, which are set forth in the following table :

Sample No.	Tensile Strength in Pounds Per sq. in.	Elastic Limit in Pounds Per sq. in.	Reduction of Area in Percentage of Area Before Test.	Elongation in Percentage of Length Before Test.
1	63,000	35,500	53	37.5
2	59,000	29,500	51	38
3	56,000	28,500	37.5	31
4	58,500	31,500	41.5	38
5	62,500	35,000	55.5	35

A view of the driver is given on page 270. It is 11 ft. 8 in. in diameter. As has been noted in describing the shaft, the latter is tapered at its upper end, and by referring to the illustration on page 270 it will be seen that a heavy key-way is cut into the tapered portion. The bearing in the driver which fits over this tapered end of the shaft is also provided with a key-way, and the driver and shaft are held together by a long and massive steel key. The driver is of mild cast steel, and was turned out by the Midvale Steel Company, of Philadelphia. It was guaranteed to have a tensile strength of about 60,000 lbs. per sq. in., but the tests of samples of steel, taken from the casting near the periphery of the first driver, showed a tensile strength of 74,700 lbs. per sq. in., an elastic limit of 44,590 lbs. per sq. in., an elongation of 30 per cent. in 3 in., and a reduction of area of 43 per cent. The surface of the fracture was silky and fine-grained. The drivers are turned on their outside surfaces and are strengthened by six deep ribs on the inside.

Perhaps the most interesting part of each generator is the field magnet ring, which not only illustrates the wonderful physical properties of nickel steel, but demonstrates in a most striking manner the perfection of modern forging ma-



TEST PIECES FROM THE GENERATOR SHAFT.

chinery and the skill of those who use it in the great plant of the Bethlehem Iron Company, at South Bethlehem, Pa. The ring is forged in one piece without weld, and is shown in the photographic reproduction on the following page. The Bethlehem Iron Company guaranteed that the rings for the first three generators should have a tensile strength of not less than 70,000 lbs. per sq. in., an elastic limit of 38,000 lbs. per sq. in., and an elongation of about 25 per cent. in 2 in.; but they have done much better. Three samples, cut from the first ring before

NICKEL STEEL FIELD RING, FORGED WITHOUT A WELD BY THE BETHLEHEM IRON COMPANY. DIAMETER, 11 FT. 7⅛ IN.

turning were tested with the following results :

Sample No.	Tensile Strength Measured in Pounds Per sq. in.	Elastic Limit Measured in Pounds Per sq. in.	Elongation in 2" Measured in Percentage of Original Length.
1	82,915	53,560	27.05
2	81,110	47,230	25 75
3	82,140	49,280	22.5

The following brief account of the method of making the field rings is based upon notes furnished by Mr. R. W. Davenport, second vice-president of the Bethlehem Iron Company. A nickel steel ingot, 54 inches in diameter at the bottom, 197 inches long, and weighing about 120,000 lbs., was cast solid, and compressed by hydraulic pressure when fluid and during solidification. This ingot is shown in the illustration on page 274. A hole was bored through its longitudinal axis, as shown on page 275, and a block of proper weight was then cut from the ingot. The cylinder thus formed was brought

to a forging heat, and expanded on a mandril under a 14,000 ton hydraulic press. The high degree of skill, and the perfection of mechanical appliances required to expand part of the cylinder, shown on page 275, to the ring, illustrated on page 272, are evident, and reflect much credit upon the Bethlehem Iron Company. After forging, the ring was carefully treated to obtain the physical qualities desired, and was then bored and rough-turned on a large boring mill. It was finally turned true in the shops of the Westinghouse Electric & Manufacturing Company, at Pittsburg, Pa.

Not only are the physical properties of the ring extraordinary; in size it is without precedent, and to those interested in the recent remarkable improvement in the quality of steel, and in the methods of working it, the interest which attaches to this ring, as an example of the finished product of the Bethlehem Iron Company, is not less than that which it derives from the important part which it sustains in the Niagara installation.

Why it is necessary that these rings should be so strong, and that they should be so forged as to eliminate the possibility of weakness in any part, will be better understood when we consider the speed at which they revolve, and the weight of the pole pieces and field bobbins which they carry. The illustrations on page 276 show one of the field poles without its winding, and one of the field poles with bobbin in place. The poles are of mild open-hearth steel, and were cast by the Midvale Steel Company. Their magnetic qualities have been carefully tested by sample, and are excellent.

The field winding, which consists of copper conductor of rectangular section, thoroughly insulated, is contained in ribbed brass boxes or covers, one of which is well illustrated on page 276. The weight of each pole piece with its bobbin is 2800 lbs. The relation of the pole pieces and bobbins to the ring is shown in the illustration on page 277. The speed of the ring at its periphery is 9300 ft. per minute when making 250 revolutions per minute, and at this speed the centrifugal force, due to each field pole and bobbin, is 2727 lbs. The strain is, of course, a maximum at a point in the ring midway between each pair of adjacent poles. The strain due to the mass of the ring itself is 2325 lbs. The total maximum strain in the ring at 250 revolutions per minute is, therefore, by calculation, 5052 lbs.

It is not sufficient that the ring should be simply strong enough to withstand the centrifugal force due to the field poles, bobbins and its own mass when revolving at 250 revolutions per minute; it must be able to run safely at a much higher speed, for it is conceivable that, should anything happen to the apparatus which governs the turbines, a much higher speed may be attained. It was judged necessary, therefore, to so design the machine that it should be safe when running at a speed of 400 revolutions per minute, and at this speed the centrifugal force due to each pole piece and bobbin becomes 6500 lbs. The strains in the ring have been, as may be supposed, calculated with great care, and even at 400 revolutions per minute, equivalent to 241 feet per second at the periphery, the total strain will not exceed 13,000 lbs. per sq. in. As the elastic limit of the material used in the rings is 48,000 pounds, the factor of safety at this speed, which will probably never be realised in practice, is nearly four. At a speed of 800 revolutions per minute, which means 482 feet per second, or nearly six miles per minute at the periphery, the ring would burst. But it is, of course, impossible that any such speed could, under any circumstances, be attained; in fact, the calculations of the designers of the hydraulic machinery show that the speed could in no case exceed 400 revolutions per minute.

Above the driver in the illustration on page 254 are the collector and brushes by which the current is conveyed from the exciters to the revolving field of the generator. The conductor conveying the field current comes from the exciters through covered conduits beneath the level of the floor, passes

SOLID INGOT OF FLUID COMPRESSED STEEL USED FOR MAKING THE FORGED FIELD RING. LENGTH, 197 IN. DIAMETER, 54 IN. WEIGHT, 120,000 LBS.

through an iron pipe concealed in the capstone of the foundation, up one of the hollow iron columns supporting the bridge or platform across the machine, and thence, along the bridge, to the brushes. From the collector rings it passes under the driver through the shaft, and thence, along one of the ribs inside of the driver, to the field bobbins. The collector rings are built upon a separate cylindrical casting placed above the driver, and securely fixed to the hub of the latter by heavy screws through a flange at its base. The brush-holder rods are held in place by a heavy iron bracket encircling the casting below the collector rings. This bracket rests upon the bridge which spans the machine.

Balancing the Revolving Field.

The longitudinal and transverse sections of the power house and wheel-pit, showing turbines, shafts and generators in place, reproduced on pages 262 and 263, illustrate the relation of these elements in the plant more graphically and exactly than is possible in a mere verbal description. The turbines are so designed that they and the shaft and the revolving part of the dynamo above them are supported upon the water passing through the wheels. By calculation, the force of the water tending to lift the shaft and generator varies from about 149,000 lbs. to about 155,000 lbs., depending upon the amount of water passing through the turbines, which, in turn, depends upon the amount of current which the generator is delivering to the circuits. The weight of the shaft and revolving part of the generator is very nearly 152,000 lbs. The difference between this weight and the upward

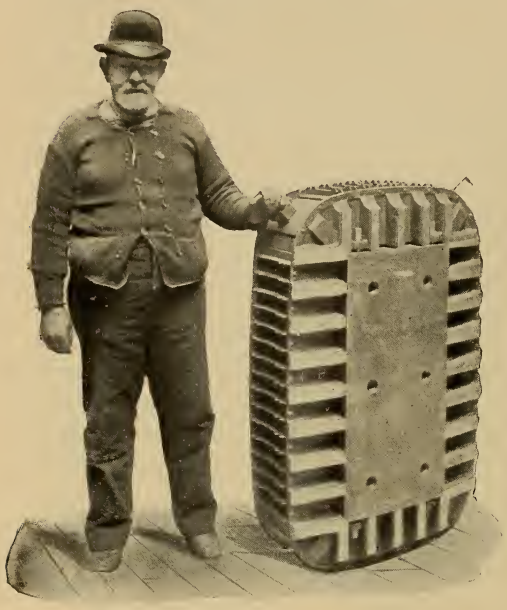
thrust of the water is taken care of by the thrust bearing located on the third gallery above the turbines. When the upward thrust of the water exceeds 152,000 lbs., the collars on the steel shaft are pressed upward against the grooves in the bearing in which they revolve, and when the upward pressure is less than 152,000 lbs. the collars are drawn downward by gravity against the grooves in the bearing. This pressure, however, whether upward or downward, in direction, never exceeds 3500 lbs. in amount, and this, of course, puts very little work upon the bearing.

The entire revolving parts of each unit of the plant, therefore, consisting of the turbines, the dynamo field and the shaft, 166 feet in length, constitute a huge top, the weight of which is practically carried upon the water in the turbines. The bearings on the first and second galleries of the wheel pit, and the upper and lower bearings in the generator, are simply guides for the shaft, to keep it in a vertical position, while the thrust bearing on the third gallery acts as a guide, and also carries the relatively small difference between the weight of the revolving mechanism and the upward thrust of the water. The turbines, shaft, and generator field revolve at the high speed of 250 revolutions per minute, and it is obvious that all of the revolving parts, especially the heavy generator field, weighing about 70,000 lbs. and measuring nearly 12 feet in diameter, must be balanced with the utmost accuracy to prevent vibrations which might become dangerous.

The method employed in balancing the revolving element of the generators is illustrated on page 278. A special shaft was placed in the bearings of the machine, and supported at its lower end by a thrust bearing into which oil was pumped at a pressure of about 1000 lbs. per sq. in. This pressure was sufficient to lift the weight of the revolving parts,

COMPRESSED STEEL INGOT WITH HOLE THROUGH CENTER, PREPARATORY TO FORGING.

and the collars on the shaft were separated from the grooves of the thrust bearing by a thin layer or film of oil. A small piece of tool steel was set into the upper end of the shaft, a half sphere or cup being cut in its upper surface, and in this was placed a tempered steel ball,



A FIELD POLE WITH WINDING IN PLACE. WEIGHT, 2800 LBS.

⅜ in. in diameter. A large eyebolt with a similar piece of tool steel, having in its lower surface a cup bearing similar to that at the top of the shaft, was secured in the tapered bearing of the umbrella-shaped driver, to the periphery of which the field ring is bolted. The entire weight of the driver and the ring was thus supported upon the small steel ball.

A casting, clamped to the shaft, served to rotate the driver and ring with the shaft. A section of this casting and of one of the ribs of the driver is shown in the illustration. The steel ball, as will be noted, was placed a very short distance above the centre of gravity of the field and driver, and under these conditions, the driver and ring being free to rock while rotated, a defect in balance was quickly shown. As a matter of fact, in the case of the first generator the driver at first assumed the position indicated by the dotted lines. This was corrected by riveting to the driver a wrought iron plate, the weight of this plate and the distance from the axle of rotation being experimentally determined to obtain not only exact static balance, but also exact running balance.

The driver was first balanced in this manner, independently. The ring was then bolted to the driver, and the two were balanced together as shown in the illustration. It was unnecessary to balance the combination of the driver, ring and field poles since the field poles and bobbins were separately weighed, and their weights adjusted to exact equality, while the positions in which they are bolted to the ring are exactly symmetrical with reference to each other and to the axis of rotation.

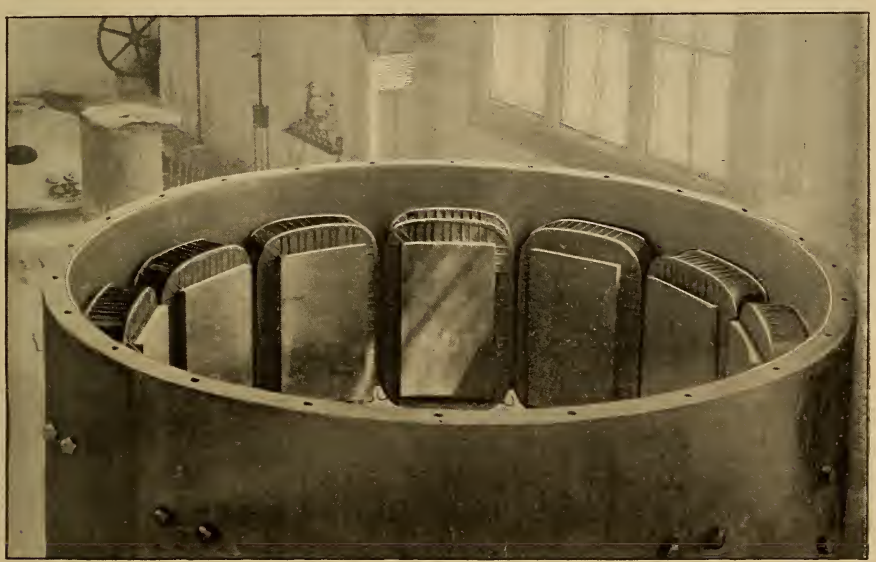
Organization of Apparatus in the Power House.

The organization of apparatus constituting the system adopted, that is,

A FIELD POLE.

the inter-relation and the functions of the generators, step-up transformers, step-down transformers, motors, commutating machines and other appa-

ratus, has been described in a general way in the early part of this article. I have also explained the construction of the generators,—the most important unit of apparatus in the plant. It remains now to describe the means adopted for controlling the heavy currents delivered by the generators, and for delivering these currents to the supply circuits which convey them from the power house to the premises of the users of power.



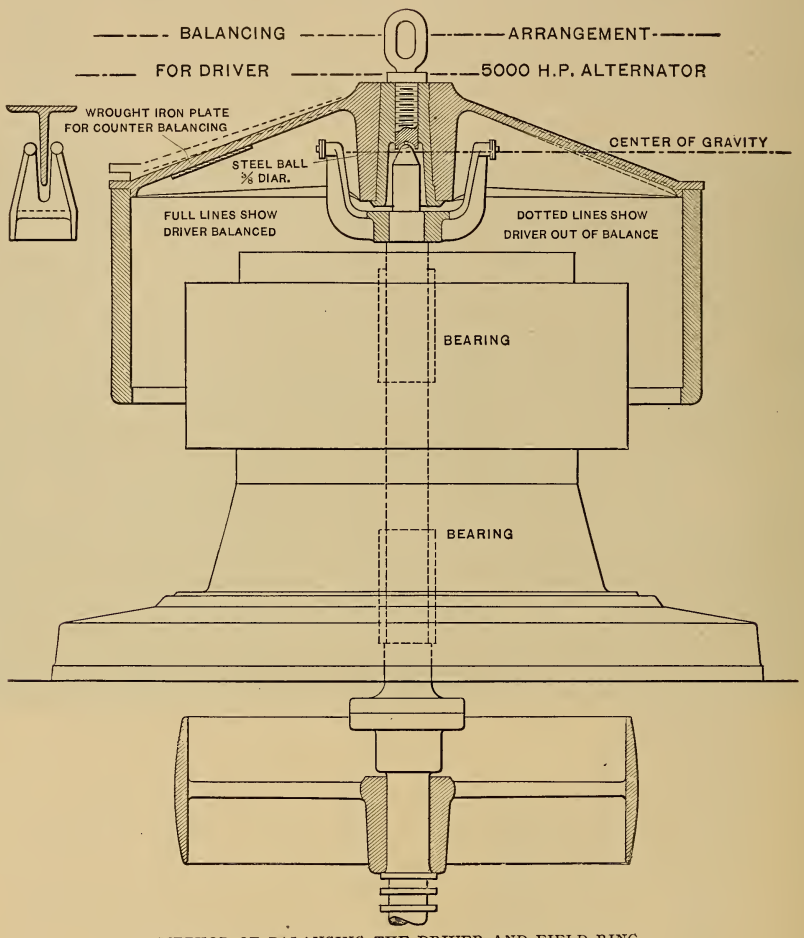
FIELD RING WITH POLES AND BOBBINS IN PLACE.

In deciding upon a plan of station organization, we face, at the outstart, two very serious conditions :—First :—The forces with which we are dealing are, in amount, far beyond the range of experience. Second :—The plan adopted must be capable of almost indefinite extension without radical modification, and without involving loss of symmetry.

We are dealing with energy in units of 5000 horse-power, developed under conditions which are, in many respects, without precedent ; and while, at the outstart, there are to be installed but three generators, the fact must be kept in mind that others will be added to the installation, and that, when the number of generators shall have increased from three to thirty or twice thirty, the organization and means provided for operating them must still be symmetrical and consistent in all its parts. The plan adopted contemplates an arrangement in groups of five generators each. The switching and regulating apparatus, and the indicating and measuring instruments, are concentrated in a swithboard centrally located with reference to each group. Provision is made for cross-connecting the several groups to be ultimately installed in this power house and in other power houses which may be erected on both the American and Canadian sides of the river in order that continuity of service may be doubly assured.

The switchboard is the centre from which the brain and hand of the operator control the mighty forces of Nature which are here compelled to do work,—it is the bridge of the ship. From it, imprisoned energy, aggregating 25,000 horse-power,—electric energy, eager to escape, seeking for the smallest pinhole in insulation, and concentrating instantly at that pinhole, if

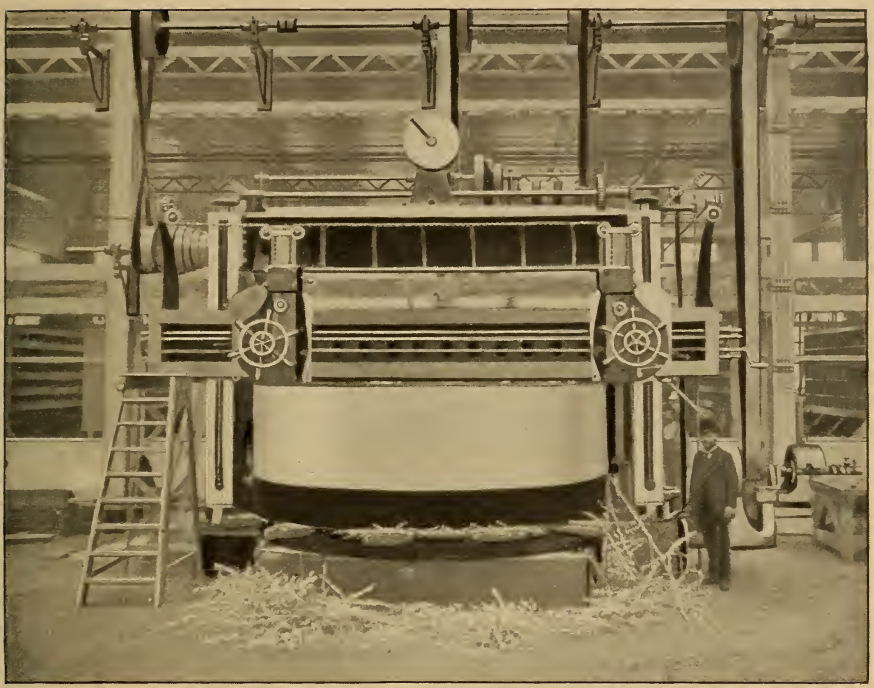
found,—must be controlled, combined, subdivided and directed. It is evidently desirable to operate the generators in parallel, this method tending to improve regulation of speed and potential, insuring continuity in the delivery of current to the users of power, and house, and the latter referring to the service which will supply consumers in Buffalo and other distant places. This consideration makes it probable that it will prove convenient and desirable to operate the generators in two sets, for the following reason :—



METHOD OF BALANCING THE DRIVER AND FIELD RING.

minimizing the necessity of opening switches conveying heavy currents of high potential in circuits of very considerable inductance and capacity. But it is also evident that the service will, in the near future, divide itself into two classes, which we may call "local service" and "long-distance service," the former referring to the service which will supply consumers within a radius of a few miles from the power

Distribution of electricity at constant potential is strictly analogous to the methods commonly employed in supplying gas and water. Each consumer has a small, independent circuit through which he draws his supply from the distributing mains, and he may open or close this circuit without in any way interfering with the supply to his neighbours, provided the potential or pressure in the network of mains is kept

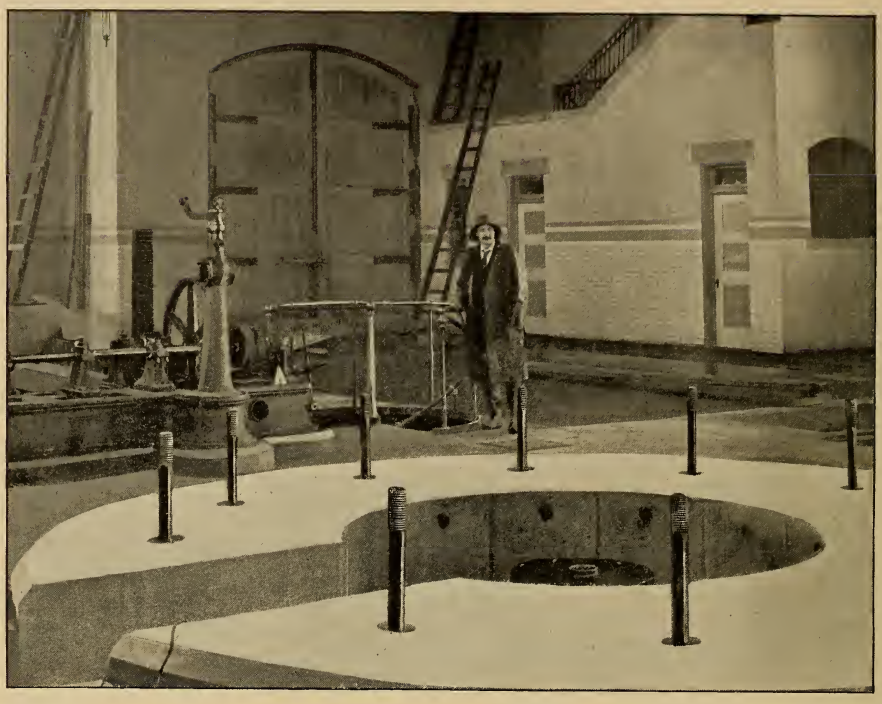


TURNING THE FIELD RING IN THE WESTINGHOUSE SHOPS.

constant. For satisfactory service, this last provision is a necessity,—the potential in the distributing mains must be constant. The local circuits at Niagara are supplied direct from the power house, through feeder or supply circuits of comparatively short length, and, consequently, the loss of potential, or drop, as it is technically called, will, in these circuits, not exceed one or two per cent.

The distributing mains in Buffalo, however, will be necessarily supplied from feeders extending from the power house, a distance of about twenty miles, and in these feeders, unless a very high potential be used, the drop will vary from a maximum of, say, five or possibly ten per cent., depending upon the amount of copper in the circuits, down to one-half, one-fourth or one-tenth of these percentages, depending upon whether the current transmitted along the feeders is the full load current for which these feeders are designed, or one-half, one-fourth or one-tenth of the full load current. It follows that at certain times during each day the potential delivered to the long-distance feeders must exceed that delivered to the local feeders by a not inconsiderable percentage, and the readiest means to meet this condition is to operate the generators in two sets or groups, the units constituting each set working in parallel.

When two or more generators work "in parallel," they are so connected that their currents are delivered to a set of large conductors, called "bus bars," just as two engines, belted to the same line shaft, deliver the power which they develop to that shaft. By suitable devices, such as friction clutches or fast and loose pulleys, either engine may be put into service, or shut down without stopping the line shaft; and, in a similar manner, any electric generator of a group may be made to add its current to that of another generator or group operating in parallel with it, or may be shut down without interfering with the



ONE OF THE GENERATOR FOUNDATIONS.

continuity of the supply of energy delivered by the group.

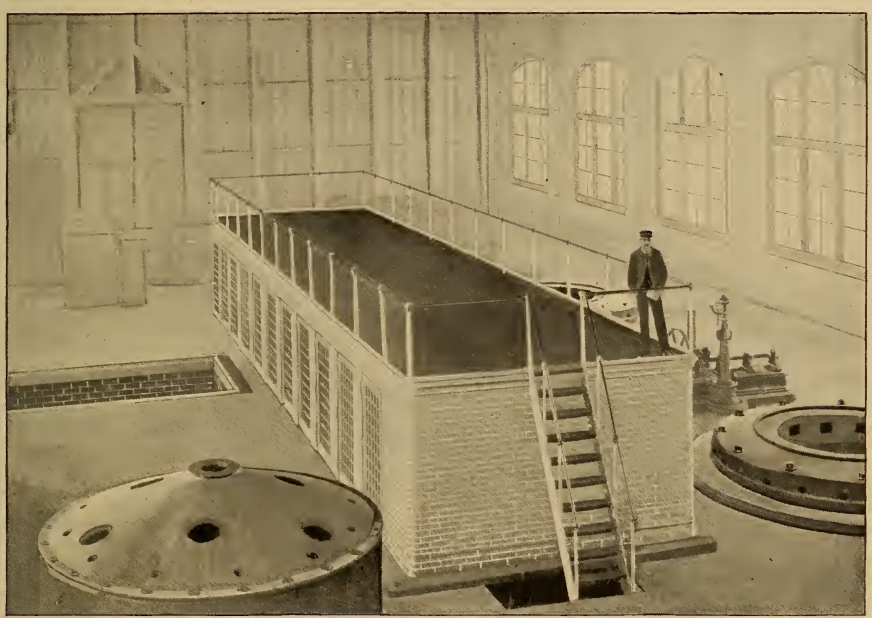
As an alternative to the plan of operating the generators in two groups, they may all be operated in one group, provision being made for adjusting the potential in either the local mains at Niagara, or the distant mains in Buffalo, by special regulating devices. For a limited number of generators this latter plan offers some advantages, but, looking forward to the time when a dozen or a score of generators will be installed, the method of operating in two groups appears preferable.

In the case of transmission to places more remote than Buffalo, it will be necessary to adopt special means for regulating potential in the distributing mains, at least until the time when improved methods of insulating circuits shall make it practicable to employ very high potentials. When that time comes, the drop in the circuits between the power house and the city of Buffalo will become so small that we may treat the Buffalo feeders as local circuits and can supply them with current from the same bus bars that are used in supplying power in the immediate vicinity of the power house; and when the practicability of commercially employing these very high patentials, *e. g.* 25,000 or even 50,000 volts, is demonstrated, transmission to places more distant than Buffalo will naturally be undertaken. Here again the second set of bus bars will be useful. The diagram on page 282 illustrates the connections of generators, generator switches, bus bars, feeder switches and local and long-distance feeder or supply circuits. To avoid complication but two generators and one long-distance and one local feeder are shown. The currents are conveyed from the generators 1 and 2, to the generator switches, S, S″, through insulated cables, each made up of 427 tinned wires. The aggregate section of copper in each cable is 1 sq. in. Through the generator switches the currents from the respective generators pass at the

will of the engineer in charge, to either of the two sets of bus bars A, B. Each set consists of four thoroughly insulated copper conductors, the construction of which will be again referred to. The switches are operated by compressed air, controlled by levers mounted on iron stands placed upon the platform above the switchboard structure within which the switches are located. By them any one of the generators, or any combination of the five generators constituting the group, may be connected to either set of bus bars.

Each switch has two separate and independent air cylinders, by which the two ends of the switch are independently controlled. The construction of the switch is shown in the illustration on page 292. To charge the bus bars A with current from the dynamo, 1, the switch is closed at one end, establishing connections between four points in the horizontal row of terminals, marked *a*, and the four points *b*. To connect the dynamo to the bus bars B, the switch is closed at the other end, establishing metallic connection between the four terminals in the row *c*, and the four terminals in the row *d*. If the two sets of bus bars are to be charged with the same potential we may supply both from the generator, 1, by closing both ends of the switch simultaneously. Similar connections are, of course, possible in the case of the other generators and the bus bars.

The feeder switch S′ is similar in construction to the dynamo switches, but the connections are different. So far as the feeders are concerned, it is not necessary that we should be able to connect them to more than one set of bus bars. Until long-distance transmission is begun, either set of bus bars may be used, or both may be charged from the same generator or generators, in which case they will, of course, be charged with the same potential. When additional generators are installed, and long-distance as well as local service is undertaken, as I have said, it will probably be advantageous to operate the



THE SWITCHBOARD STRUCTURE.

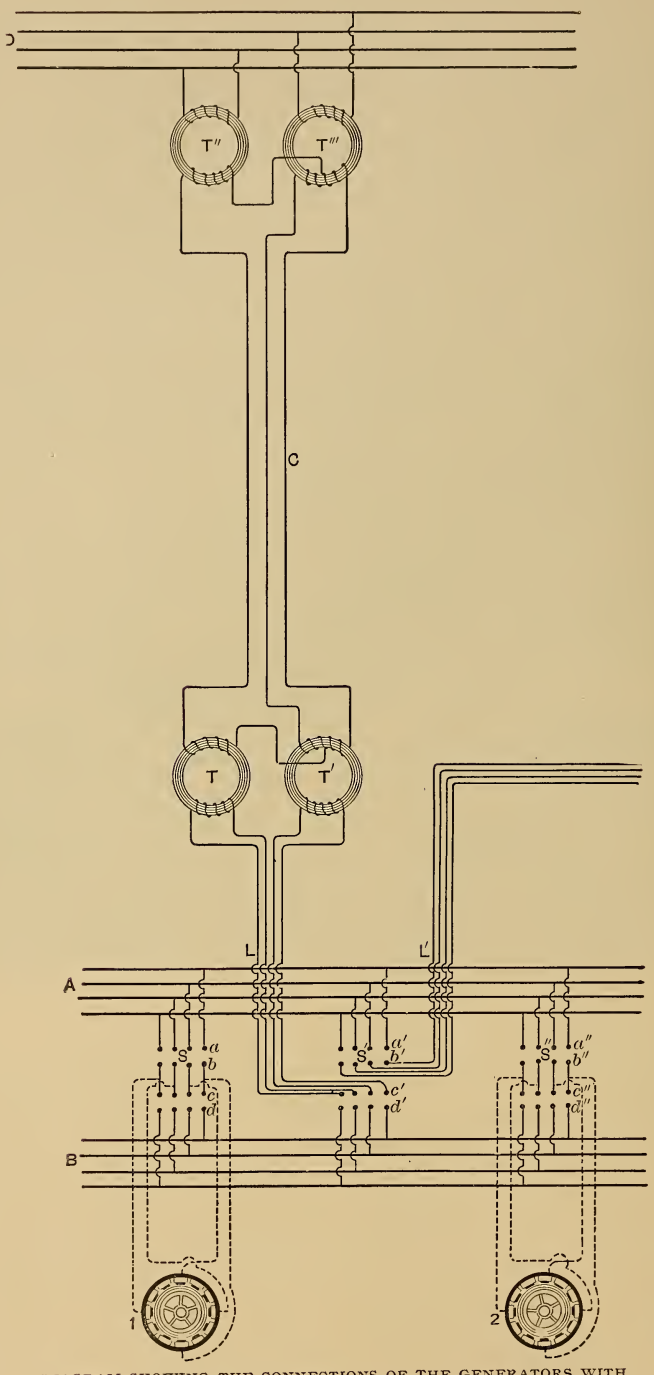
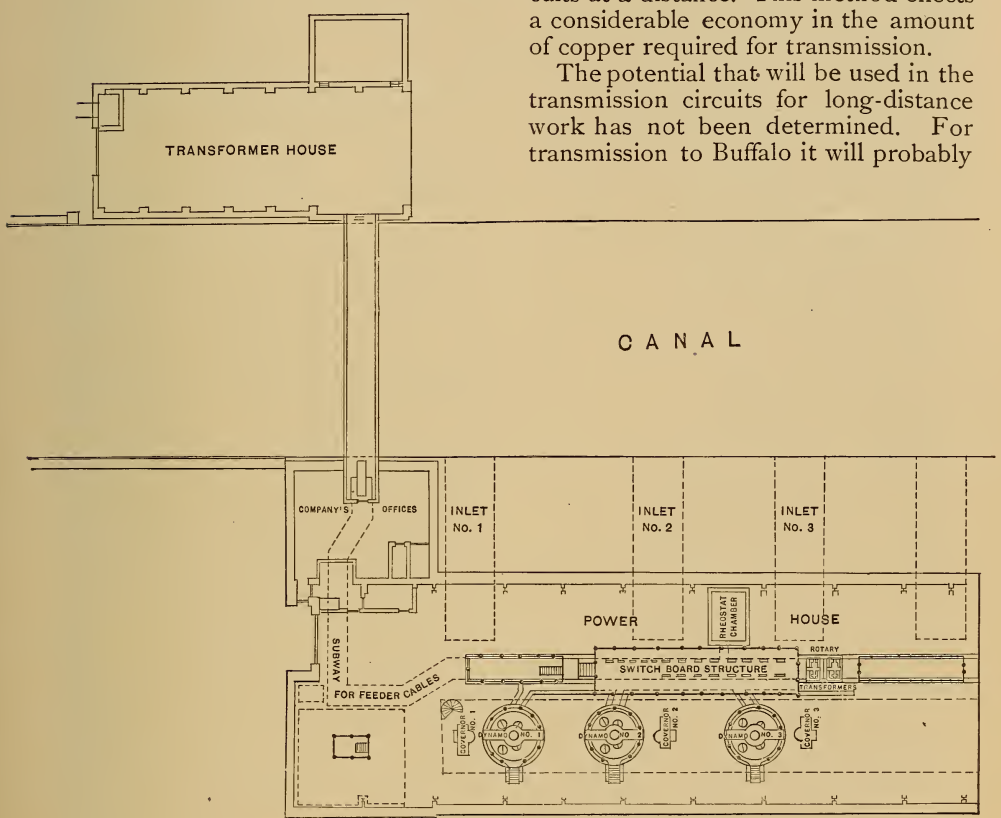


DIAGRAM SHOWING THE CONNECTIONS OF THE GENERATORS WITH LOCAL AND LONG-DISTANCE FEEDERS.

generators in two sets to permit adjustment of potential to compensate for losses in transmission. The respective local and long-distance supply circuits will then be simply arranged for connection through their switches to the local or long-distance bus bars, as desired.

In the diagram on page 282, L represents a supply circuit used for long-distance service, and L′ represents a similar circuit used for local service. In the diagram of the long-distance circuit, T and T′ are step-up transformers, used to increase the potential for transmission, while T″ and T‴ are step-down transformers, located at the distant end of the transmission circuit, for example, at Buffalo or Tonawanda. In the general diagram on page 256 is illustrated the arrangement of circuits in the case of simple two-phase transmission by four wires. The diagram on page 282 shows an arrangement of transformers by which the two-phase currents, delivered by the generators, are changed to three-phase currents in the transmitting circuits, and then changed back to two-phase currents in the local distributing circuits at a distance. This method effects a considerable economy in the amount of copper required for transmission.

The potential that will be used in the transmission circuits for long-distance work has not been determined. For transmission to Buffalo it will probably not be less than 10,000 volts, and not more than 25,000 volts. For transmission to greater distances, still higher potentials are contemplated.



PLAN OF POWER AND TRANSFORMER HOUSES.

The illustration on page 281 shows the structure erected for the switchboard apparatus. It is of white enameled brick, and is 57 ft. 10 in. long, 13 ft. wide and a little less than 8 ft. in height. It is erected directly over the sub-way, as shown in the floor plan on page 283. The top of the structure is of slate sup-

ported upon iron I-beams, and the platform thus formed is surrounded by a neat brass hand-rail. The sub-way beneath the switchboard is spanned at suitable distances by iron I-beams, to which the dynamo and feeder switches are bolted in place. The cables passing from the generators through ducts beneath the floor line are connected to the generator switches, while the outgoing cables, constituting the feeder or supply circuits, drop directly from the feeder switches into the subway. Iron standards are secured to each side of the subway by expansion bolts. They are placed at intervals of about 4 ft., and adjustable iron brackets set into these standards support the lead-sheathed cables passing through the sub-way and bridge to the transformer house on the east bank of the canal.

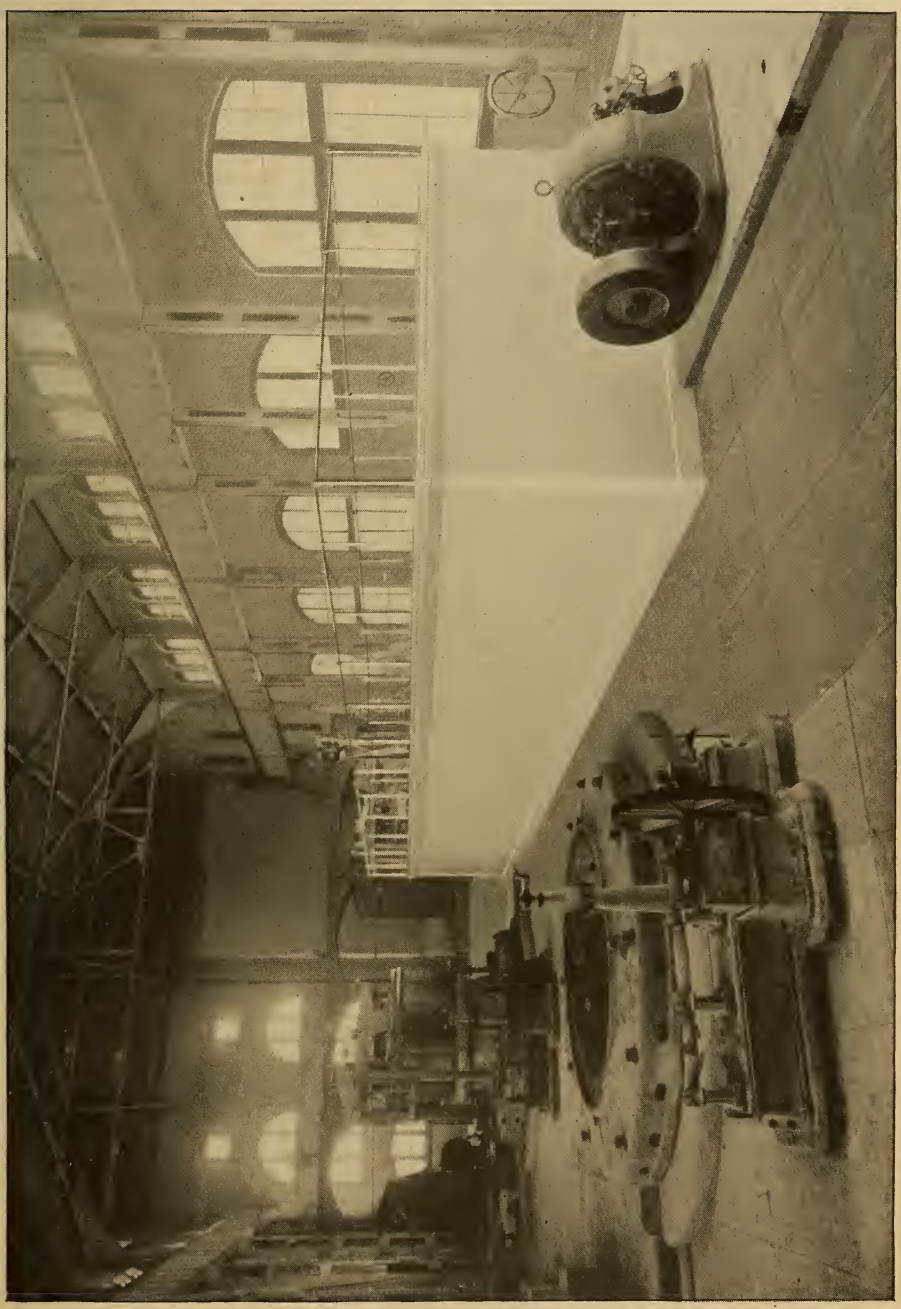
The drawing on page 283, showing the floor plan of the power house, bridge and the transformer house, will make clear the position of the switchboard structure with reference to the first three generators and the sub-way. Additional generators will, in due time, be erected in line beyond the generator marked "Dynamo, No. 3," and the switchboard structure is designed to accommodate all instruments and switches needed in connection with the first five generators.

The organization of the switchboard apparatus and the general features of the construction of the essential elements will be best understood by reference to the illustration on page 286, which is reproduced from the official drawing. The upper part of the illustration at the reader's right hand is a front elevation of the stands which carry the instruments for the several generators and for the exciters, and also shows one of the lever stands for the feeder circuits. Beneath the floor line of the switchboard platform is seen one set of bus bars in connection with an end elevation of the generator and feeder switches. A plan of the switchboard platform is also given in the illustration on page 288, a part of the platform being cut away to show a plan of one generator switch and one feeder switch. On page 286, again, is shown a plan of the rheostat chamber and sub-way for the cables, and just above this, a section through the switchboard, sub-way and rheostat chamber, at right angles to the direction of the sub-way, is given.

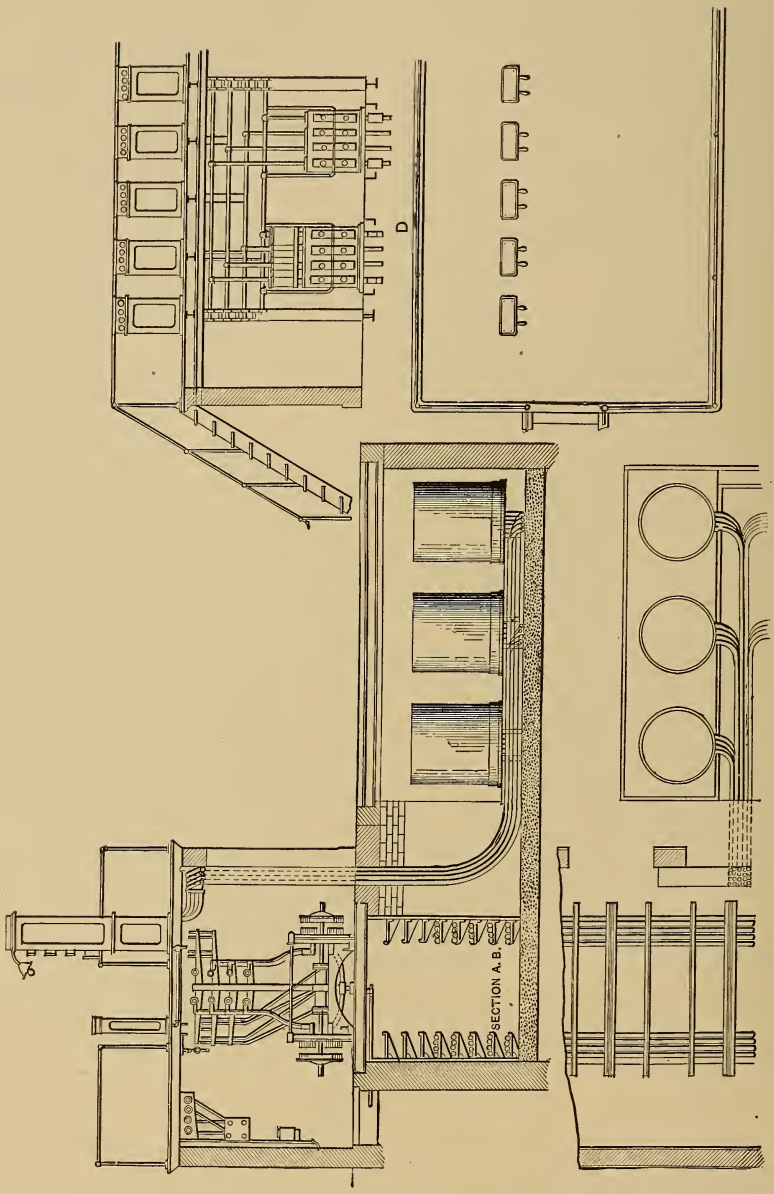
The essential elements of the switchboard apparatus are,—the generator and feeder switches, the bus bars, the switching and safety devices for the exciting currents, the rheostats for controlling the generator fields, and the indicating and measuring instruments. As shown by the plans, the switches and bus bars are located within the switchboard structure. Upon the switchboard platform are erected the instrument stands, one for each generator, two for the rotary transformers, and one for the engine-driven generator, temporarily used as an exciter, and in front of each instrument stand is placed a cast-iron stand, about 30 inches in height, carrying the levers which control the admission of air to the switch cylinders, and a wheel by means of which the rheostats are controlled.

Each of the lever stands used for controlling the large generator switches carries also levers for opening and closing the field circuit of the corresponding generator, and a hand wheel by which the rheostat resistance in the field of the generator is adjusted. The rheostats are located in a special chamber below the floor line of power house, the face-plates being located in the bases of the instrument stands. Connection between the face-plates and resistance coils of the rheostats is secured by insulated cables of suitable section. The compressed air used in operating the switches comes from a compressor direct, driven by a Worthington water motor. This compressor is located at the bottom of the wheel pit, and supplies air to a large cylindrical reservoir from which pipes are led to the various switches. The pressure used is 125 pounds per square inch.

Engineers, not familiar with the possibilities of electricity, will be impressed by the fact that the currents actually measured are not the heavy currents traversing the cables within the switch-



ONE END OF THE POWER HOUSE.



THE ORGANIZATION OF THE SWITCHBOARD APPARATUS.

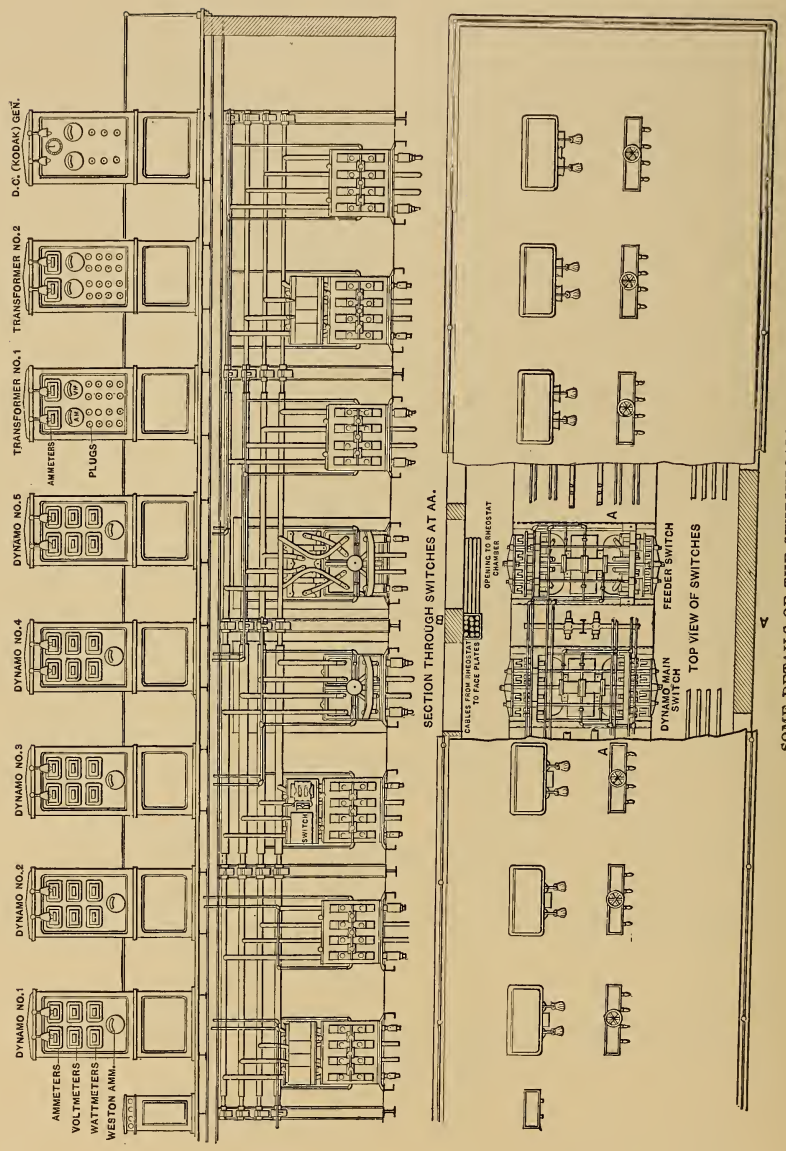
board structure, but are derived currents, bearing a known relation to the heavy currents delivered by the generators. They are small in quantity and absolutely harmless. The operator, standing upon the switchboard platform, cannot possibly touch a circuit which is in the slightest degree dangerous. The currents measured are obtained by means of transformers located inside the switchboard structure, the ratio of their winding being such that for every 50 ampères flowing in the main circuit, a current of 1 ampère is supplied from the secondary of the transformer to the measuring instruments. Currents to the respective voltmeters are supplied from transformers, the primaries of which are connected across the generator circuits. For the wattmeters both series and shunt connections from the generator circuits are needed, and these are obtained from the transformers used for the voltmeters and ammeters.

To measure energy, current and potential in each phase of each generator, two converters, an indicating wattmeter, an ammeter and a voltmeter are employed. The energy required by these devices amounts, as a maximum, to about 30 watts—that is, $\frac{1}{25}$ horsepower. It is an extraordinary illustration of the facility with which electricity is accurately measured that we should be able thus to determine energy varying from 25 horse-power to 2500 horsepower by means of measuring devices, accurate throughout their range within one per cent., and requiring for their operation not more than $\frac{1}{30}$ horsepower.

The instrument stands are boxes or cabinets, constructed of iron and marble, the front of each, above the pedestal, being formed of a single slab of polished Italian marble, $1\frac{3}{4}$ inches thick, 30 inches in width and 45 inches in height. Each stand occupies a floor space of 38 inches by 20 inches and is 7 feet in height. Sliding doors at the back give access to the measuring instruments. The marble front of the stand is pierced by six rectangular openings, and the instruments are secured to the marble in such a way that the front of each, with its scale and index, projects through the marble to the front of the stand.

The engraving on page 289 illustrates one of the alternating current ammeters, as viewed from the front. The indicating wattmeter and the voltmeter are similar in appearance. The fronts are finished in oxidised brass. These instruments, and the integrating wattmeters, used in connection with feeder circuits (not located upon the switchboard platform), comprise a remarkable group of measuring instruments recently invented and designed by Mr. Oliver B. Shallenberger, Consulting Electrician of the Westinghouse Company. As they were primarily designed with special reference to the Niagara installation, they are designated the "Niagara type" by the Westinghouse Company. Their sphere of usefulness, however, will be as wide as the applications of alternating currents. They depend for their action upon the induction of currents in a movable closed secondary circuit, and all operate to a certain extent upon the same general principles, specifically developed in each case to attain the object desired. They are extremely simple in construction, the parts are few and comparatively massive, and yet the instruments are capable of giving very accurate results. They are guaranteed by the Westinghouse Company to be correct within one per cent.

In each instrument a thin aluminium disc, stiffened by a flange around its edge, constitutes the movable element, in which eddy currents are induced by currents traversing coils placed above and below it. The relation of the induced currents in the disc and the inducing currents in the coils is such that the disc tends to rotate. In the wattmeter the tendency is proportional to a function of the energy traversing the inducing circuits, and these currents come from a converter located beneath the platform, and, in turn, are proportional to the energy in one of the gen-


DYNAMO NO.1
DYNAMO NO.2
DYNAMO NO.3
DYNAMO NO.4
DYNAMO NO.5
TRANSFORMER NO.1
TRANSFORMER NO.2
D.C. (KODAK) GEN.
AMMETERS
VOLTMETERS
WATTMETERS
WESTON AMM.
PLUGS
SWITCH
SECTION THROUGH SWITCHES AT AA.
CABLES FROM RHEOSTAT TO FACE PLATES
OPENING TO RHEOSTAT CHAMBER
DYNAMO MAIN SWITCH
FEEDER SWITCH
TOP VIEW OF SWITCHES
SOME DETAILS OF THE SWITCHBOARD.

erator circuits, which is the energy to be measured. The tendency to rotate is resisted by a torsion spring, and the currents turn the disc, overcoming the resistance of the spring through a certain angle. This angle depends upon the relative strength of the twisting moment, due to the currents and the resisting force of the spring, and the position of the disc, with reference to its position when no current traverses the coils, becomes a measure of the energy. The scale is attached to the circumference of the disc, and depends from it much as the field ring of the generator depends from the driver. This scale is carried with the disc, from its zero position, through an angle depending upon the current measured, and the instrument being once carefully compared with a standard and the scale properly marked, the energy can be determined by taking the reading of this scale opposite the index, which is always fixed in position. In the illustration on this page the index will be seen in the centre of the rectangular glass window, and, immediately behind it, an arc of the circular scale.

The ammeter, which measures the strength of the current, and the voltmeter, which measures the potential, resemble the indicating wattmeter in the fact that they are based upon the same principles, and they are also similar in general features of construction. The methods employed to obtain the proper phase relations of the currents in the inducing circuits and in the disc are very ingenious and, to the electrician, interesting. But this is not the place to describe them in detail.

The ammeters, which measure the currents in the fields of the generators, were furnished by the Weston Instrument Company, of Newark, N. J., and are of their well-known type, in which the current actually measured by the instrument is that which flows through a circuit connected in shunt to a resistance which is placed in the circuit traversed by the current to be measured.

All of the currents measured by the instruments located in the instrument stand are supplied through insulated conductors of small section, which convey the small derived currents from converters or from the terminals of resistances placed beneath the switchboard platform. Each generator instrument stand carries, in addition to the instruments already described, a phase indicator, by means of which the attendant or the engineer in charge, who desires to connect a generator in parallel with another generator or group of generators, determines the proper time for closing the switch.

The instruments provided for the stands belonging to the rotary transformers used as exciters, are not the

AN ALTERNATING CURRENT AMMETER, NIAGARA TYPE.

same as those provided for the generator instrument stands, and they also differ from the instruments provided for the stand belonging to the temporary engine-driven exciter. They comprise two Shallenberger alternating-current ammeters of the Niagara type and a direct-current ammeter and voltmeter made by the Weston Instrument Company. A number of plug contacts are provided, by means of which the ratio of conversion of the static transformers which supply current to the rotary transformers may be adjusted.

The construction of the bus bars is, in several respects, remarkable, the magnitude of the quantities dealt with again making it necessary to devise methods of construction outside the range of experience. As has been said, two sets of bus bars are provided, but it

is, of course, conceivable that under certain circumstances it may be desirable to cut one set out of service and control the output of five generators through the other set. By arranging the generator switches and feeder switches as shown in the illustration, in such a way that the former, through which current is delivered to the bus bars, alternate with the latter, through which current is drawn from the bus bars, the maximum current which it is necessary to convey through any section of the bus bars becomes that supplied by three generators. This is equivalent in each bar to about 3000 ampères, and, assuming a current density of 1000 ampères per sq. in., would require a section of about 3 sq. in. in the bus bar. The potential of the currents may be as high as 2400 volts.

A short-circuit might obviously be very dangerous, and this fact, in connection with the fact that at certain times the atmosphere of the power house is liable to carry a considerable amount of moisture, ready to be precipitated upon metallic surfaces, points to the desirability of insulating the bars. To insulate them in the most satisfactory manner, rounded surfaces are necessary, but in a round solid conductor, 3 square inches in section, nearly 2 inches in diameter, two other difficulties must be faced: First, the surface from which the heat, due to resistance, must be radiated, is small as compared with that obtained by using flat bars or straps of equal section; and, second, an alternating current in such a conductor will not distribute itself uniformly, but will seek the surface, leaving the copper at the centre relatively idle and ineffective.

These difficulties have been successfully overcome by the construction adopted. From the middle each bar tapers toward the ends. The middle section consists of a copper tube of about 3 inches outside diameter and 2 inches inside diameter. Into this, at either end is screwed a tube, the outside diameter of which is approximately 2 inches, while its inside diameter is about $1\frac{1}{8}$ in. Into the other ends of each of these tubes, in like manner, a copper rod $1\frac{1}{8}$ inch in diameter is screwed. The offsets or connections from which short lengths of cable convey current to or from the several switches, are clamped to the bar thus formed, all surfaces being rounded. The entire bar with offsets is then insulated with very high-class rubber insulation. These bars were constructed by the Brown & Sharpe Manufacturing Company, of Providence, R. I., U. S. A., according to the designs of the Westinghouse Company, and were insulated by the India Rubber and Gutta-Percha Insulating Company, of New York, the method employed being that covered by the Habirshaw patents. The insulation consists of alternate layers of pure Para gum and vulcanized rubber, two layers of each being used, and the outer layer of vulcanized rubber protected by a special braided covering chemically treated to make it non-combustible. Similar insulation is used for the cables between the generators and the switches and for the connections between the bus bars and switches.

A section of the Habirshaw cable is reproduced on the opposite page. The illustration is very nearly the exact size of the cable. The makers guarantee that the insulation of cables and bus bars, erected in place, shall stand an alternating current potential of 10,000 effective volts between copper and earth. Samples submitted and tested in the laboratory of the Westinghouse Company successfully resisted the application of potentials exceeding 40,000 volts.

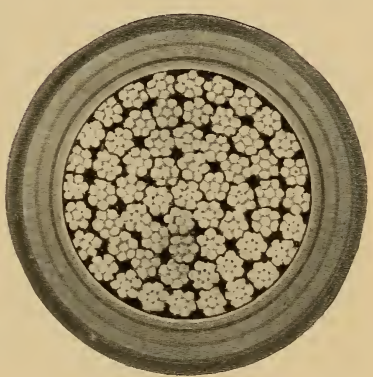
The calculated losses in a set of four bus bars conveying the full output of five generators, 25,000 electrical horse-power, are less than 10 horse-power. The radiating surface is, of course, considerably greater than it would be in the case of solid circular bars of equal section. At the ends of the bars, where the section is about 1 sq. in., the current is that coming from one generator only, and in a bar of this section the tendency of the current to seek the surface is negligible. In that part of the bar which has an outside diameter of 2 inches the current con-

veyed may be that coming from two generators, and the tendency to seek the surface would be appreciable in a solid circular conductor of equal section, while in that part of the bar which is 3 inches in diameter and which may be called upon to convey current from three dynamos, it would be very considerable. The use of the tubes instead of solid bars gets rid of the idle copper at the centre of the latter, and at the same time increases the ratio of radiating surface to section of conductor.

The construction of suitable switching devices for circuits conveying 5000 horse-power at a potential of 2000 volts is a serious problem. To be sure, the dynamos will be operated in parallel, and by proper adjustment of the field charges of the generators and the gates controlling the turbines, the current traversing the dynamo switch at the moment of opening or closing the circuit can be reduced within moderate limits. But there is always the chance that something may go wrong; the operative may make a mistake, or something else may happen, and it was, therefore, deemed necessary to construct a switch capable of opening without damage to itself or other apparatus, circuits conveying 5000 horse-power. The Westinghouse Company accordingly inaugurated a series of experiments, and detailed several expert engineers to thoroughly study the subject. The result of their work is illustrated on page 292. The opportunity has not yet been afforded to thoroughly test this switch in commercial service, but shop tests, carried out under conditions approximating to those which will be met in practical operation of the plant at Niagara, indicate that it is capable of switching very heavy currents without damage to itself, and without dangerous rise of potential.

Current for exciting the fields of the generators is obtained directly from rotary transformers, which, in turn, are supplied with alternating current from the generators, static transformers being interposed to reduce the potential. During the period of construction exciting current is also derived, when necessary, from a 75 kilowatt direct current generator driven direct by a Westinghouse compound engine. This generator and engine, together with the boiler plant for the latter, are located in a small temporary building at a distance of about 200 yards from the power house. The engraving on page 293 illustrates one of the two rotary transformers installed, and their location in the power house is indicated in the floor plan on page 283. These transformers are of 200 kilowatts output each.

As will be seen in the illustration of the complete machine, on page 259, the shaft carries a commutator at one end of the armature and a four-ring collector at the opposite end. Alternating current, at about 125 volts potential, is delivered to the collector from the secondary terminals of the static transformers, one of which is illustrated on page 294. From the commutator end of the rotary transformer, direct current, at a potential approximating 175 volts, is delivered to the fields of the generators, the field rheostats being interposed in these circuits to permit adjustment of the current flowing in each field.



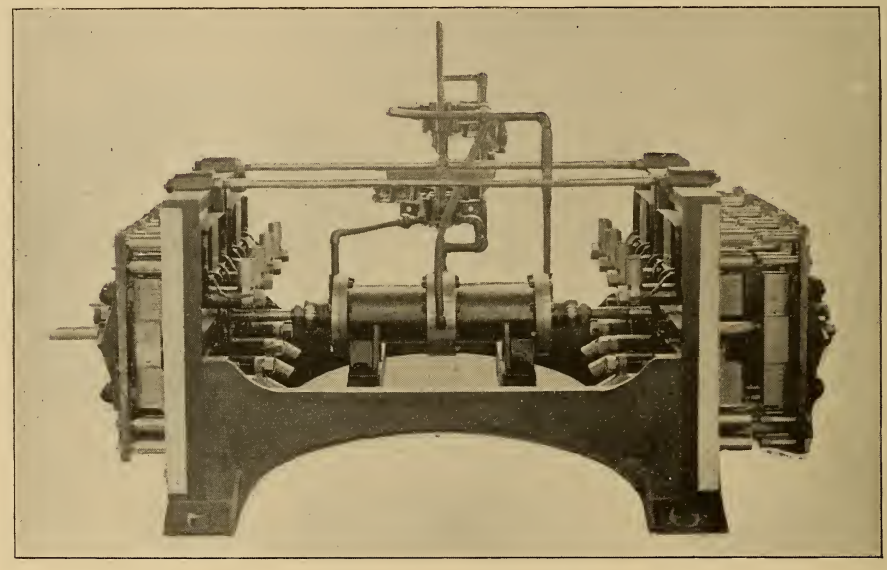
A SECTION OF THE HABIRSHAW CABLE.

The armature winding is of the closed circuit type, and each of the ring collectors is connected to a certain point in the same winding from which current is delivered to the commutator. The machine, in operation, runs as a

synchronous motor, driven by the two-phase alternating current, and delivers from the commutator continuous current, just as it would do were it driven as a generaror by a turbine or an engine. The fly-wheel at the end of the shaft is used to give steadiness of speed and to prevent what is sometimes called "pumping;" that is to say, unequal angular velocity at successive stages in a revolution of the armature, caused by the flow of idle current between the generator and the rotary transformer.

Two static transformers, each capable of delivering 100 kilowatts each, are used to supply alternating current to each rotary transformer. They are placed in cylindrical boxes of boiler iron, and are immersed in oil. This secures an extremely thorough insulation. The oil is kept cool by water, which circulates through a spiral of galvanized iron pipe, fitting closely to the inside of the cylindrical box. Each box is provided with an oil gauge by which the height of oil may be determined. Provision is made for readily drawing off the oil at the bottom of the box in case of necessity. The transformer, the box, and the spiral of pipe through which the water circulates are shown on page 295.

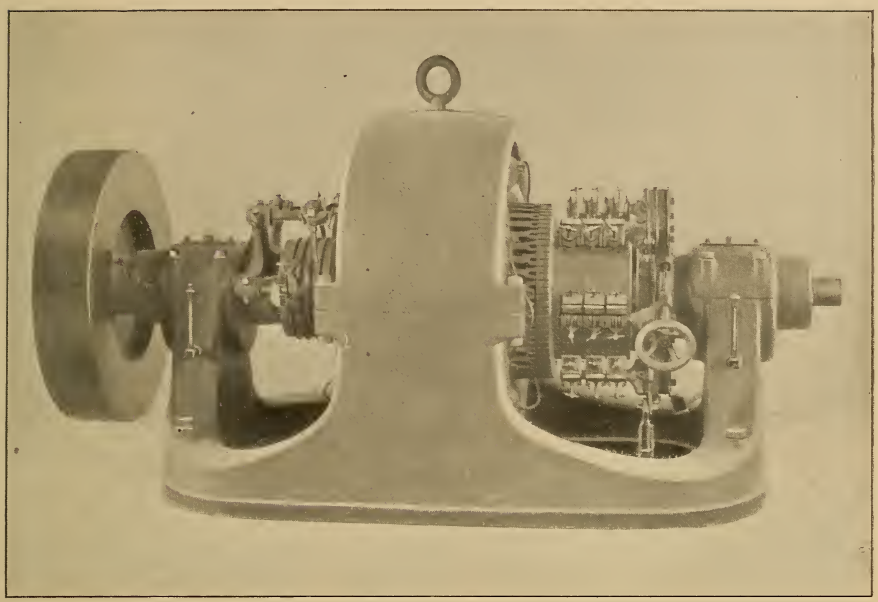
Before the generators were erected in the shops of the Westinghouse Electric and Manufacturing Company, at Pittsburgh, careful tests were made of the materials used in the construction of the various elements of the machines. Of these, the tests of the physical properties of the shaft, field ring and driver have been referred to. The special means adopted for balancing the revolving parts of the generator have also been described. Among other tests, the following are of especial interest:



ONE OF THE MAIN SWITCHES.

Tests of the Magnetic Qualities of the Field Ring.

Two samples of steel, cut from the edge of the rough-forged ring before it was turned, were tested by the permeameter method to obtain what is technically known as the B-H curve; that is, the ratio of induction to magnetizing force for various values of the latter. The B-H curve was also determined by a modification of the so-called "ring method," the entire field ring being used for this purpose. This very beautiful and interesting experiment

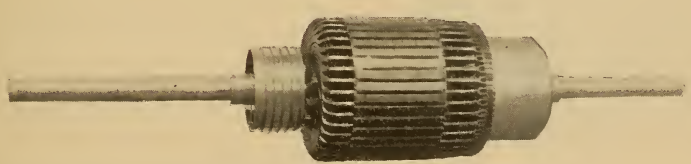


A 200 KILOWATT ROTARY TRANSFORMER USED AS AN EXCITER.

was suggested by Mr. Chas. F. Scott, electrician of the Westinghouse Electric and Manufacturing Company, and carried out under his direction.

All the measurements are illustrated graphically in the chart on page 297. Curves A and B are respectively the B-H curves for wrought-iron and cast-iron, as determined by Dr. John Hopkinson of London, and are here given for purposes of comparison. Curve C is the B-H curve for nickel, as determined by Prof. J. A. Ewing. Curves D and E are determined by permeameter from samples cut from the edge of the ring. Curve F was determined by the ring method, using the entire field ring. The very high values of the induction, for all except very low magnetizing forces, are remarkable.

The tests by the ring method indicate higher values of the induction for moderate magnetizing forces than were obtained by the permeameter. The former is the more reliable method, and curve H undoubtedly represents very closely the true relation of induction and magnetizing force in the field ring of the first generator. The permeability of the field ring is, therefore, considerably higher than that of standard wrought iron.



ARMATURE OF THE ROTARY TRANSFORMER.

For the purpose of balancing the driver and field ring, and to make mechanical and electrical tests as complete as was practicable in the shops where no 5000 horse-power engine was available to drive the generators under full load, each machine was erected in such a manner that the weight of the

revolving element was carried upon a collar or thrust bearing at the bottom of the shaft. Into this bearing oil was forced by a pump, at a pressure approximating 1000 pounds per square inch, the result being that the collars on the shaft and the corresponding grooves in the bearing were thoroughly lubricated. The oil was kept in circulation so that it might not become excessively heated.

That the friction in the bearing was reduced within very moderate limits was demonstrated during some of the later tests, when, the driving belt coming off the pulley suddenly when the machine was running at about 250

A 100 KILOWATT TRANSFORMER.

revolutions per minute, the field continued to revolve for thirty-nine minutes by reason of its own inertia.

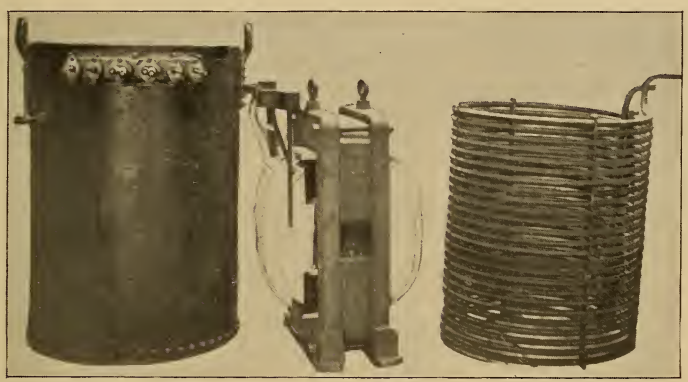
Determination of the Potential Curve.

As is now pretty well understood by those who are in any way interested in engineering, the potential at the terminals of an alternating current generator varies from zero to a positive maximum value, then to zero, then to a negative maximum value, and then to zero again, this cycle being continuously and rapidly repeated, in the case of the Niagara generators twenty-five times per second. One half of such a cycle is graphically represented by the chart on page 298, in which the solid line is the curve of potential at the terminals of the first generator, as experimentally determined. The dotted line is a sine curve, representing an electromotive force of equal effective value. Horizontal distances, measured along the base or zero line, represent time, while the vertical distances, measured from the base line to the potential curve B, represent difference of potential at the generator terminals. At any given instant, represented by a certain point on the base line, the difference of potential is proportional to the vertical distance from that point to the curve.

In the determination of the form of the potential curve at the terminals of the first Niagara generator, a method, suggested by Mr. B. G. Lamme, of the engineering staff of the Westinghouse Electric and Manufacturing Company, was adopted, and carried out as follows: The machine being set up, as above described, a steel cable was secured to the outside of the field ring, about which it was wound to the extent of a half-dozen turns. The free end of the cable was then secured to a vertical shaft placed in a boring mill. The latter, being revolved at slow speed, the cable was wound upon the shaft, and the field of the generator was slowly revolved as the cable unwound from the field ring. In this way an extremely slow speed (about one revolution in five minutes, or one cycle in fifty seconds) was obtained.

A field charge which, at 250 revolutions per minute, would induce an electro-motive force of 2500 volts in the armature, would, at this speed, induce about 2 volts in the armature circuits. Voltmeters, capable of reading accurately to $\frac{1}{100}$ of a volt, were connected directly across the terminals of the armature, and, as the field revolved, readings were taken at intervals of three

seconds, these intervals being timed by an observer, while two others read the voltmeters, and two assistants recorded the readings. This test was repeated many times with very close agreement in the results. It is due to Mr. Scott, Mr. Lamme and Mr. McLaren, of the technical staff of the Westinghouse Company, to say that the results, when plotted to the same scale as the theoretical curve which they calculated before the test was made, can scarcely be distinguished from the actual curve determined by experiment.



DETAILS OF THE 100 KILOWATT STEP-DOWN TRANSFORMER.

By the efficiency of the generator we mean the ratio of electrical output to mechanical input; that is to say, the quotient obtained by dividing the amount of energy delivered to the circuits by the generator, by the energy delivered to the shaft of the generator at the top of the long shaft which connects the generator and the turbine. This quotient is expressed as a percentage of the input. The difierence between the input and output of energy is represented by the various losses in the generator.

These losses are mechanical, electrical and magnetic. The mechanical losses are those due to air friction of the revolving parts of the generator, and the friction of the two bearings which guide the generator shaft. The electrical losses are those due to the main or primary current traversing the armature conductors, the exciting current in the field winding, and eddy currents which may be set up in the armature conductors, in the core of the armature, in the field poles and in the field bobbins. The magnetic losses are those due to the magnetization of the core of the armature, which is, of course, alternating in sign, and to fluctuations in the magnetization of the field. Not all of these various losses can with convenience or accuracy be segregated, but fortunately, practically all that are of special importance can be measured. Tests were, therefore, made at the Westinghouse factory which determined the efficiency of each machine with a very fair degree of accuracy. They were made with great care, and in the case of the first generator all important measurements were repeated many times. This is not the place for a complete statement and discussion of the tests made, which, in itself, would be as long as this entire article, but the methods employed and the results obtained may be briefly summarized.

As the generator was erected in the shops, the revolving element was sustained, as already stated, by a collar or thrust bearing. A direct current motor, capable of delivering 200 horse-power, was used to drive the generator, the motor being turned upon its side, so that the shaft, supported upon a thrust bearing, was vertical, and, therefore,

THE AMERICAN FALLS AT NIAGARA.

parallel to the shaft of the generator. The field of the direct current motor was independently excited, and readings of the current and potential, delivered to its armature from a direct current generator, driven by an engine, were taken in a series of tests, which were repeated several times during a period of about two weeks. The results show that when the field of the generator was not charged by exciting current, it was necessary to deliver to the motor 76 horse-power to drive the

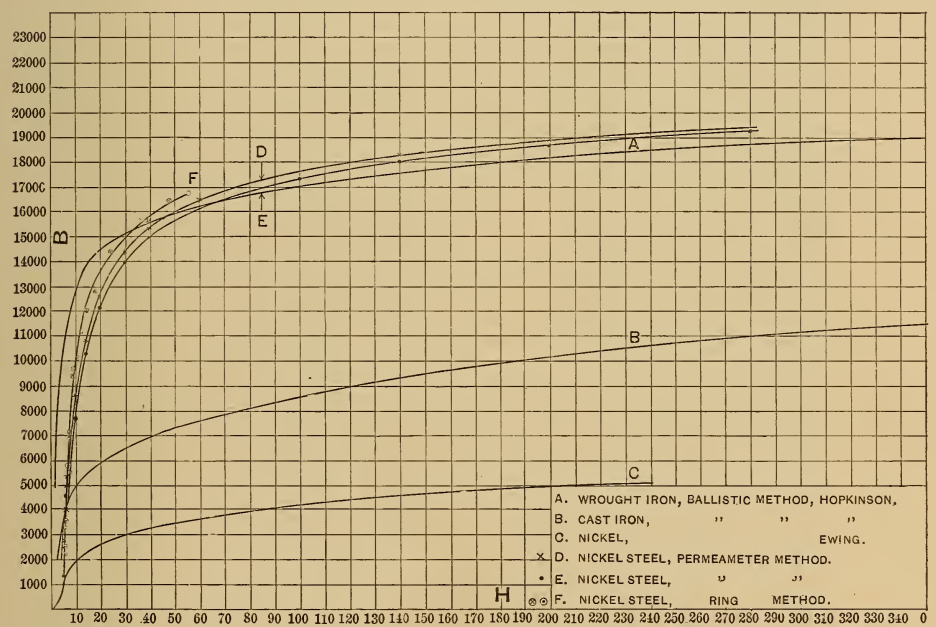


CHART SHOWING THE MAGNETIC QUALITIES OF THE FIELD RING.

generator field at a speed of 250 revolutions per minute. The belt connecting motor and generator being taken off, 26 electrical horse-power were required to drive the motor at the same speed as before. The difference between these two quantities, or 50 horse-power, represents the mechanical friction in the generator, made up of air friction, the friction of the two bearings which guide the shaft, the friction of the step-up or thrust bearing at the bottom of the shaft, and also the loss in the belt, which was necessarily kept very tight. Just what this belt friction, and the increased friction in the bearings, due to tightness of the belt, amounted to could not be easily determined, nor was any attempt made to segregate the loss in the thrust bearing from the other losses.

This loss in the thrust bearing is not properly chargeable to the generator, since the machines, as erected at Niagara, have no thrust bearing above the point in the shaft where the power is delivered to the generator. It can safely be said, therefore, that at Niagara the total mechanical losses in the generator will be less than 50 horse-power, —that is, less than one per cent. of the power required to drive them.

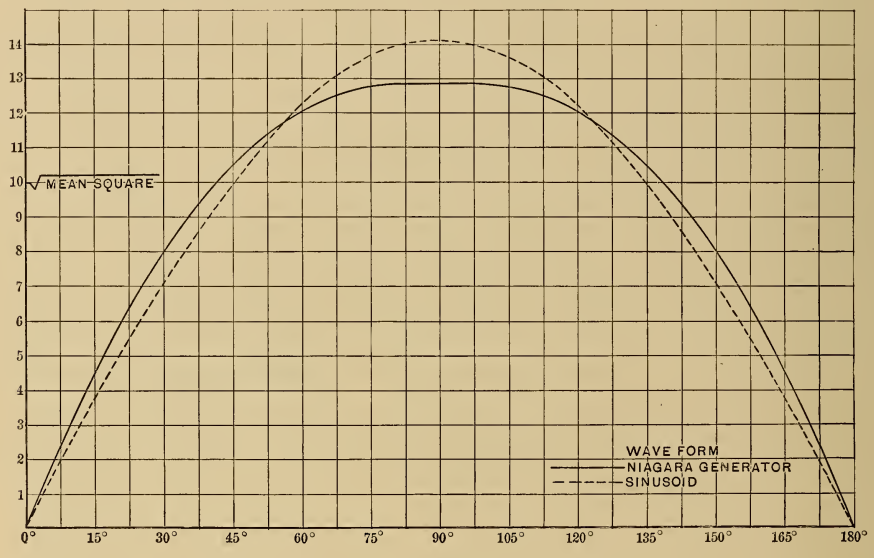
The determination of the amount of energy represented by the current which excites the field of the generator is easily made. The method employed was to charge the field, beginning with a very small current, and increase this by successive steps until the potential at the terminals of the armature, at a speed of 250 revolutions per minute, approximated 3000 volts, taking at each

step simultaneous reachings of the current in the field, the potential at the field terminals, and the potential at the armature terminals. The field current was then gradually reduced, simultaneous measurements being taken as before of the current in the field, the potential at the field terminals, and the potential at the armature terminals. In this way the field current required to induce in the armature, without load, any given electromotive force not less than 500 volts and not greater than 3000 volts, was determined. From this the field current which corresponds to any armature potential when the generator is loaded,—that is, when the armature is delivering current,—can be determined with close accuracy by calculation.

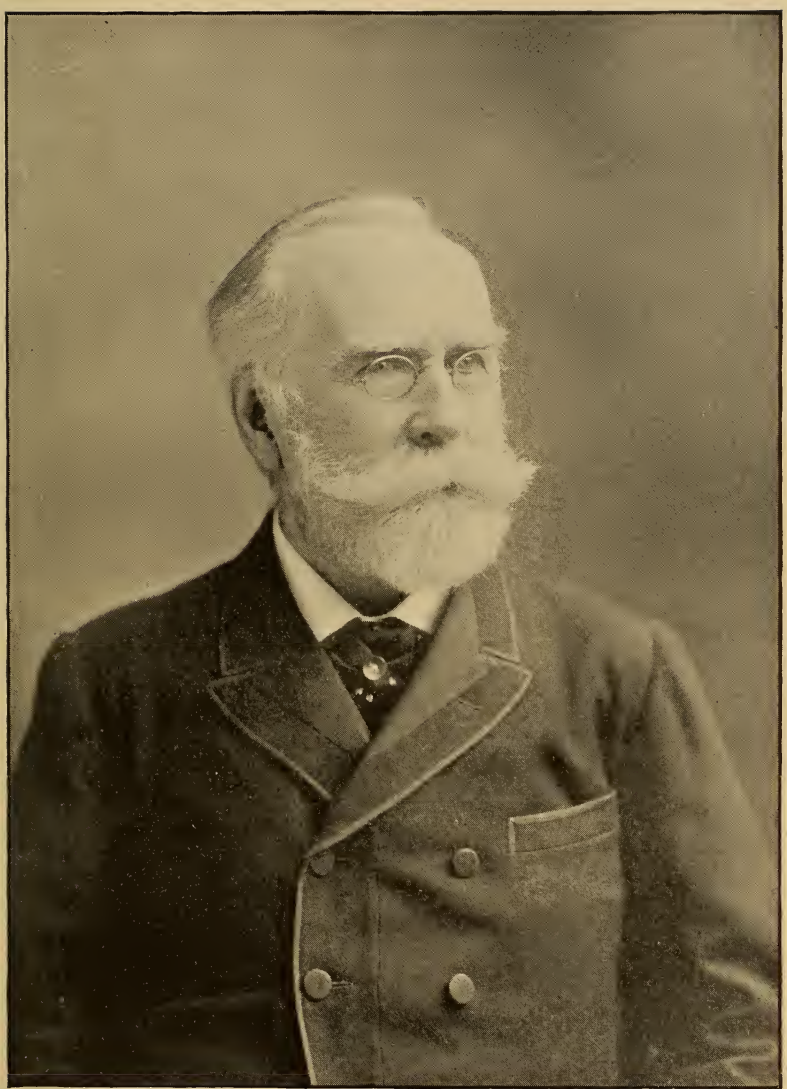
With some types of machines this would not be so easily done, but in these generators the relations existing between the armature and field are similar to those which exist in many of the large generators employed in street railway service, and in making the calculation, therefore, we are not far removed from the safe basis of experimental fact. In this way it was determined that under conditions which will exist at Niagara, the field current in each generator under full load will in no case exceed 15 horsepower.

The next loss to be determined is that due to the magnetization of the armature core. This is made up of two factors, but for our purpose, these need not be differentiated from each other. The test was made as follows : The generator being driven at a speed of 250 revolutions per minute by the direct current motor, measurements of the electric energy delivered to the latter were made coincidently with measurements of the potential at the terminals of the generator armature. As the current in the field of the generator is varied, by adjusting resistance in its circuit, the magnetization of the armature, of course, varies, and the potential at its terminals is a measure of the magnetization, or, more strictly, induction in the armature core.

As the magnetization increases, more power is required to revolve the field, the difference in the power delivered by the motor to the generator for any given potential at the armature terminals (that is, for any given degree of magnetization), and the power required to drive the field at the same speed with



THE POTENTIAL CURVE FOR ONE OF THE GENERATORS.



Coleman Sellers

DR. COLEMAN SELLERS, one of the best known engineers on both sides of the Atlantic, is the consulting engineer of the Cataract Construction Company, and is also president and chief engineer of the Niagara Falls Power Company.

De Courcy May -

De Courcy May was the engineer and general superintendent of the Cataract Construction Company during the installation of the wheelpit machinery.

no magnetization being accounted for by the core loss. As already stated, the energy required to drive motor and generator, as determined in the case of the first machine, is 76 horse-power, and by subtracting this amount from the amounts required to drive the generator with any given magnetization in the core, we have a closely accurate measure of the loss.

In this way it was determined that the amounts of power delivered to the motor, corresponding to potentials at the armature terminals varying from 2000 to 2400 volts, were as follows :

2000 volts	121 − 76 = 45	horse-power
2200 "	130 − 76 = 54	"
2400 "	141 − 76 = 65	"

Were the armature in service, delivering currents representing the full output of the machine, the distribution of the magnetic lines in the armature core would be somewhat, but not very radically different, and consequently these measurements do not tell us exactly what the loss in the core will be under conditions of actual service. But, making a fair allowance for an increased loss due to this and other minor causes which may make themselves felt in the commercial operation of the generator, it would seem safe to say that the loss in the armature core, operating at 2100 volts, which is about the voltage at which those generators supplying local service will be operated, will not exceed 60 horse-power.

The loss due to the current in the armature conductors could not be accurately determined from tests in the shop. This loss, however, is easily calculated with close accuracy from measurements of the resistance of the armature conductors and the known value of the full load currents which they will carry in service. Disregarding possible eddy currents in the conductors, which, from the construction, should be almost negligible, calculations show that the loss in the armature conductors under full load will not exceed 30 horse-power. Theory indicates that other losses, with the possible exception of eddy currents in the field poles, will be so small as to be practically negligible, and including the loss in the field poles, which could not be readily determined, their amount will not be sufficient to materially affect the efficiency of the generator.

To sum up the mechanical, electric and magnetic losses, when the generator is delivering current at 2100 volts, we have roughly the following:

Maximum loss in field copper	15	horse-power
Loss in armature core	60	"
Loss in armature conductors	30	"
Total	105	"

To arrive at the actual efficiency of the generator we must add to this the losses due to air friction and friction of the bearings, but the tests do not indicate to what these amount, except that with the loss in the thrust bearing used during the shop tests they did not exceed 50 horse-power. With the losses in the thrust bearing charged against the generator (which is, of course, unfair to the machine) we have for the total mechanical, electric and magnetic losses 155 horse-power. In order that the generator shall deliver 5000 horse-power to the circuits it is, therefore, necessary that 5155 horse-power be transmitted to it through the shaft. Dividing 5000 horse-power, the output, by 5155 horse-power, the assumed input, we have almost exactly 97 per cent. From all this it appears perfectly safe to say that the generators, under the conditions of commercial service, will, at full load, operate at an efficiency exceeding 97 per cent. At the time of writing this, the tests of the generators as erected in the power house at Niagara are not yet completed.

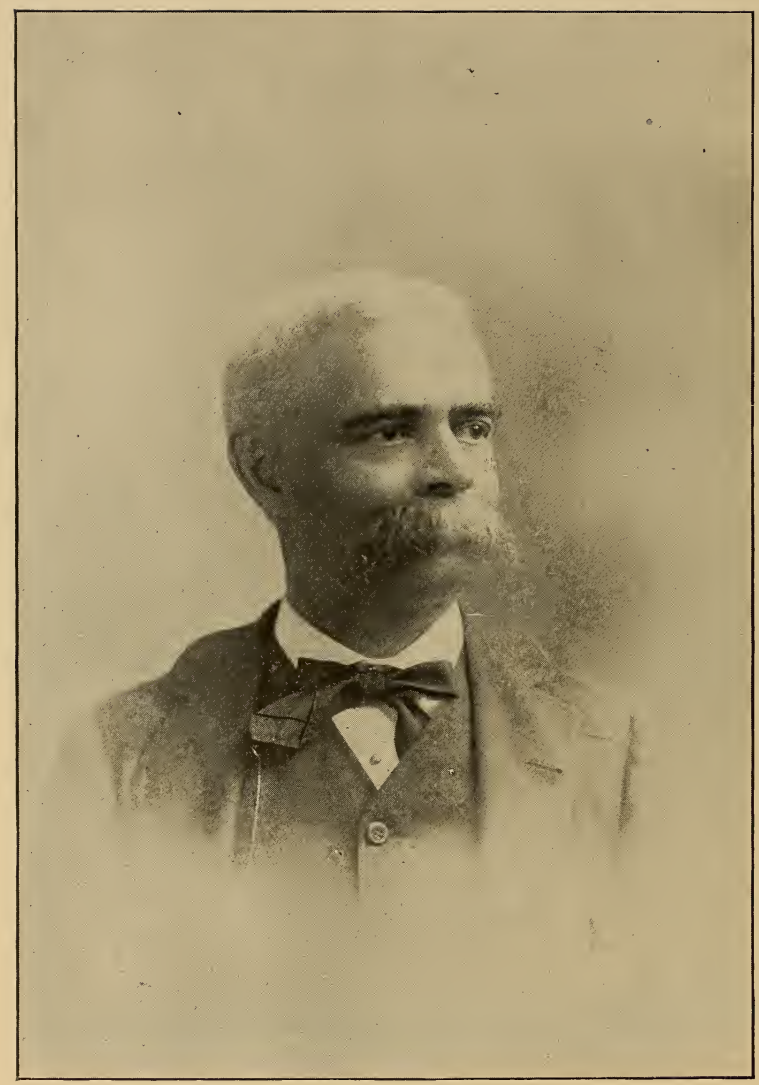
The description of the electric generating plant in the foregoing pages is necessarily incomplete. Much that would interest scientific specialists is omitted or merely glanced at, and on the other hand, space and time have not permitted the attempt to elucidate statements which, to those not familiar with electric work, must appear more or less obscured by technical phraseology. This I cannot hope to amend.

The tests of the first 5000 horse-power unit are now in progress, and success is assured. When, on the

morning of April 4th, 1895, Mr. Rudolphe Baumann, the Swiss engineer, who has for several years devoted his skill and energy to perfect the hydraulic plant, gently moved the hand wheel which controls the first turbine, the field of the generator began to revolve, noiselessly, irresistibly, testifying to the skill and painstaking effort of the civil, hydraulic, mechanical and electrical engineers, whose combined efforts, directed by the splendid enterprise of the Cataract Construction Company, have united in producing a 5000 horse-power unit of machinery, capable of transforming the energy of falling water to electric energy, live, vibrant, needing only suitable conductors to guide it across miles of country, to places where it may turn the wheels of a thousand mills and factories.

The Niagara generators were constructed by the Westinghouse Company, following, as regards mechanical form, the type of machine proposed by the engineers of the Cataract Construction Company. This was fully described by Prof. George Forbes in a paper read in November, 1893, before the British Institution of Electrical Engineers. The auxiliary electric apparatus, including exciters, switching devices, measuring instruments, etc., were designed and constructed by the Westinghouse Company, assisted, as to the bus bars, by the Brown & Sharpe Manufacturing Company, of Providence, R. I., U. S. A., and the India Rubber and Gutta Percha Insulating Company, of New York.

Among those who have been particularly prominent in the work are: Mr. Albert Schmid, general superintendent; Mr. C. F. Scott, electrician; Mr. Philip Lange, superintendent; Mr. O. B. Shallenberger, consulting electrician; Mr. B. C. Lamme, Mr. E. C. Means, Mr. H. P. Davis; Messrs. Sigfried, Wright, Boegel, W. F. Lamme, Beinitz, Alberger, Mirault, Friedlander, Strauss, Mould and Parks. To Dr. Coleman Sellers, president and chief engineer of the Niagara Falls Power Company, and Mr. De Courcy May, late superintendent and engineer of the Cataract Construction Company, who, in consultation with Mr. Schmid and his assistants, made many valuable suggestions, the thanks of the Westinghouse Company are also due.



John Bogart

JOHN BOGART is one of the consulting engineers for the Cataract Construction Co., and, as such, has taken a prominent part in most of the work pertaining to the great Niagara enterprise.

THE MAIN STREET.

THE INDUSTRIAL VILLAGE OF ECHOTA AT NIAGARA.

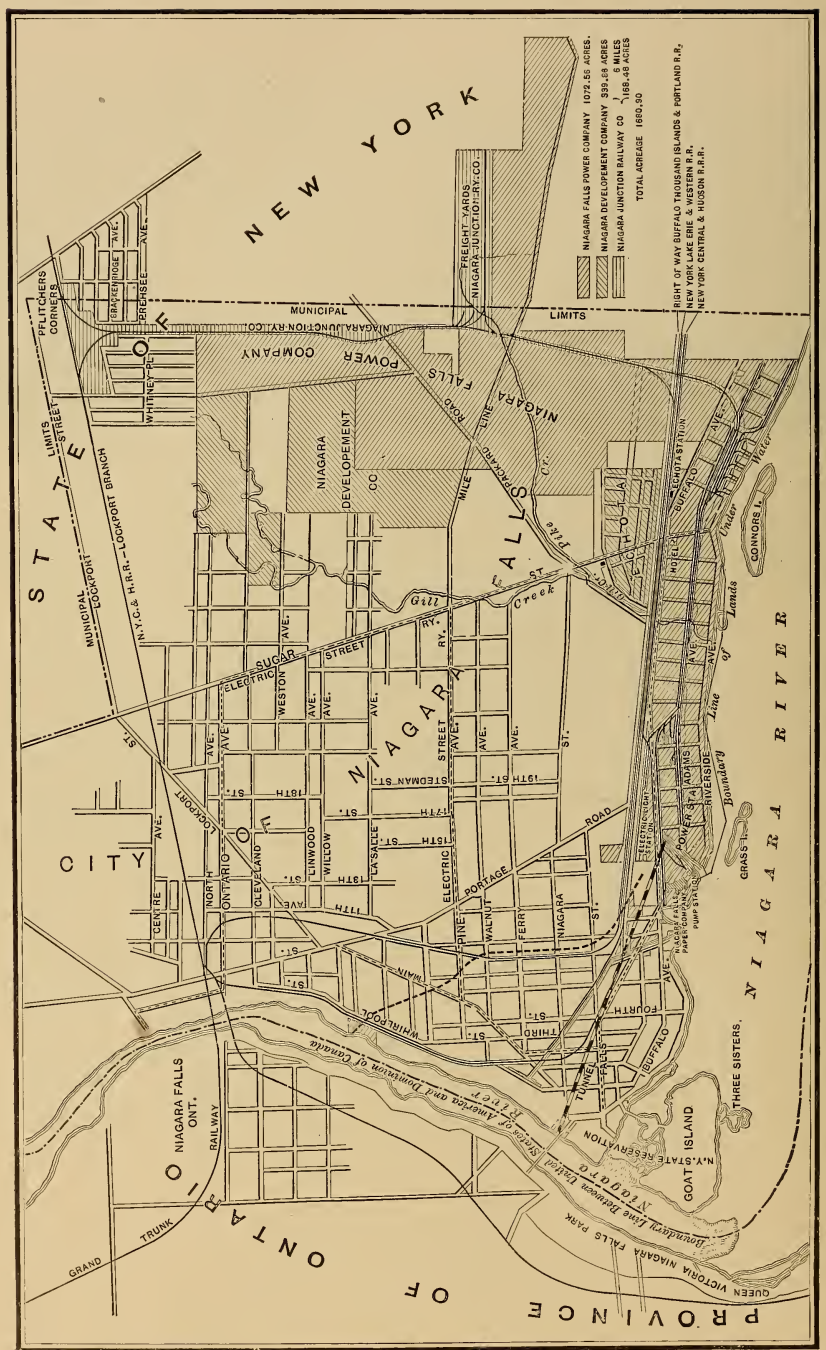
By John Bogart, M. Am. Soc. C. E.

THE lands of the Niagara Power Company extend about two and one-quarter miles along the right bank of the Niagara river. The enormous mechanical power there available, either by the direct use of water or by electrical transmission, will bring to these lands very large industrial establishments, some of which have been, in fact, already built, even before the power which they require could be furnished to them.

With such industries must come a large population of skilled labour operatives, mechanics, experts, foremen, clerks, accountants, superintendents and proprietors. It is in all respects desirable that the homes for these men and their families should not be too far from their work, and, therefore, the company owning the lands determined to create a residence neighbourhood which should have comfortable houses, with all practicable conveniences, with attractive surroundings, and which could be rented at very reasonable rates. A location was chosen near the centre of the lands of the company, and upon eighty-four acres, thus selected less than two years ago, there is now a very complete village.

The story of so speedy a development of an industrial village, a description of the plans adopted and of the methods of executing the constructions demanded by those plans should not be, under any circumstances, uninteresting. But in the case of this village of Echota, there were a number of special conditions which presented peculiar difficulties in determining the best solution of the various problems incident to a successful result.

The land upon which the improvements have been made is of oblong, but not exactly rectangular, shape, about 3000 feet long in a direction parallel with the Niagara river, and about 1500 feet in width. The river bank is distant about 1000 feet from the nearer line of the village. The whole area, both of the village and of the land between it and the river, is very flat, sloping very slightly to the bank. Over the whole eighty-four acres of meadow on which the village has now been laid out, there was an extreme variation of surface of four feet. The



LANDS OF THE NIAGARA POWER AND DEVELOPMENT COMPANIES.

general average level of the river, 562 feet above tidewater at New York, is about three feet lower than the lower parts of the village, but the water of the river occasionally rises to very nearly the elevation of this village surface. It was, therefore, impracticable to carry the drainage of these grounds to the river, with sufficient fall in pipes or gutters to quickly relieve the surface from the water of rainfalls, while to carry the requisite sub-drainage directly to the river was simply impossible.

The western boundary of the village is a stream of very moderate and sluggish flow in ordinary seasons, but suddenly expanding and overflowing with an enormous volume of water at times of heavy rainfall or sudden thaw. A branch of this stream, with the same characteristics, runs just north of the village line. The place is thus exposed on two sides to the overflow of these streams, and, in fact, the whole area of the village was covered with water of considerable depth soon after the beginning of the works of improvement.

Under a few inches of loam which covers these grounds, there is a stratum of about eight or nine feet of blue clay, then a red clay, and then a compact gravel and clay overlies the rock, which is found at depths of not less than fourteen feet. In their natural state these fields were in very bad condition for long periods after every rainfall, and during the gradual melting of the winter snow. The water gathered in shallow pools. There was not sufficient general surface slope to carry it away, and it could not pass through the tenacious underlying clay. It disappeared only by evaporation. Experimental excavations for cellars of houses retained water as tenaciously as well-cemented cisterns. The land during these seasons was wet, sticky and heavy, and when the water did evapo-

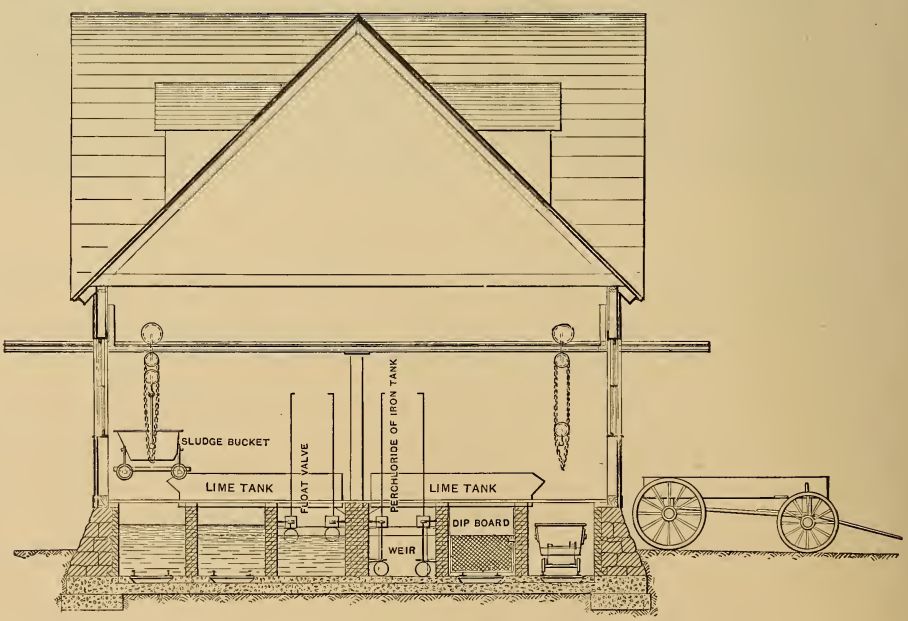
ANOTHER STREET VIEW IN ECHOTA.

THE SEWAGE DISPOSAL WORKS.

rate, the ground became baked and seamed with wide and narrow cracks in the hard clay soil. The roads in the vicinity were either very dusty or very muddy.

One of the features of the design is that every house shall be provided with a dry cellar and shall have a fair garden area. The plans for the streets also contemplate considerable grassy surfaces and ample provision of shade trees. It was, therefore, essential that the soil should be always in fit condition to maintain grass, lawns, trees, gardens and flowers.

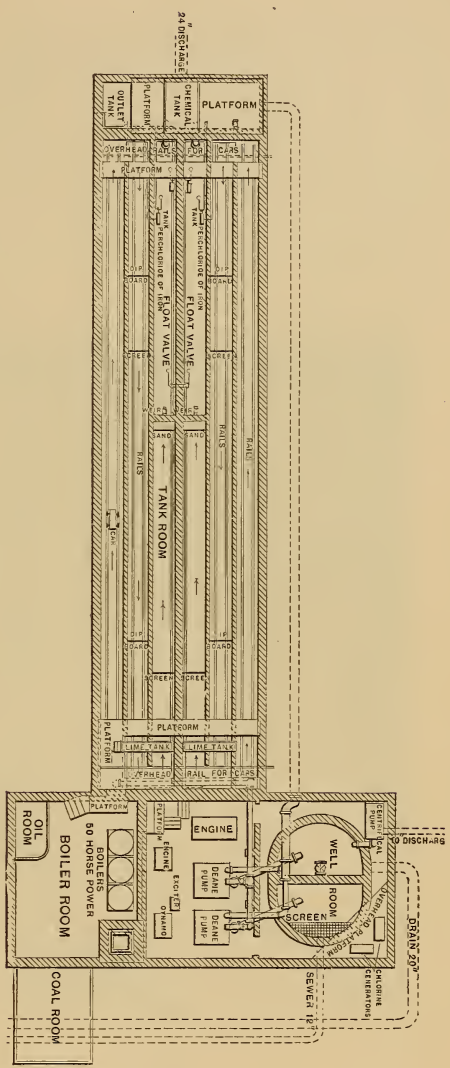
Streets and roads cannot be kept in good order nor taken care of economically unless thoroughly under-drained.



SECTION AND ELEVATION OF THE SEWAGE DISPOSAL BUILDING.

Furthermore, and of still greater moment, it would have been criminal to have invited families to take up their abode in houses built upon ground in such condition. Malaria and kindred diseases would have had a fertile field. But the waters, both of the small stream bounding the village, and of the Niagara river, some distance away, were at too great an elevation to receive even the rainfall running over the surface, to say nothing of the water taken from the subsoil deeply enough to give the free drainage required.

It was necessary also to provide an outlet for the sewage of the houses, and the elevation of the streams made a direct discharge into them impracticable. A discharge of this drainage and sewage into the lower river below the Falls, would have been possible, but it would have involved the construction of a conduit of great length, which, to secure the necessary gradient, would have been mostly in deep rock excavation and would have necessarily been of considerable size to provide, in addition, for the sewage of all the district lying between Echota and the lower river. The authorities of the city of Niagara Falls did not feel that it was necessary, at present, to extend their sewer system to Echota and the consulting engineer of the Niagara Development Company found a much less expensive method of providing fully for its needs. It will, however, be practicable to directly connect both the drainage and sewerage systems with the extended trunk lines of the city sewers when they reach Echota. The receiving well and the disposal house have been located particularly with this in view.



PLAN OF STATION FOR WELLS AND PUMPS, SEWAGE DISPOSAL AND ELECTRIC LIGHTING.

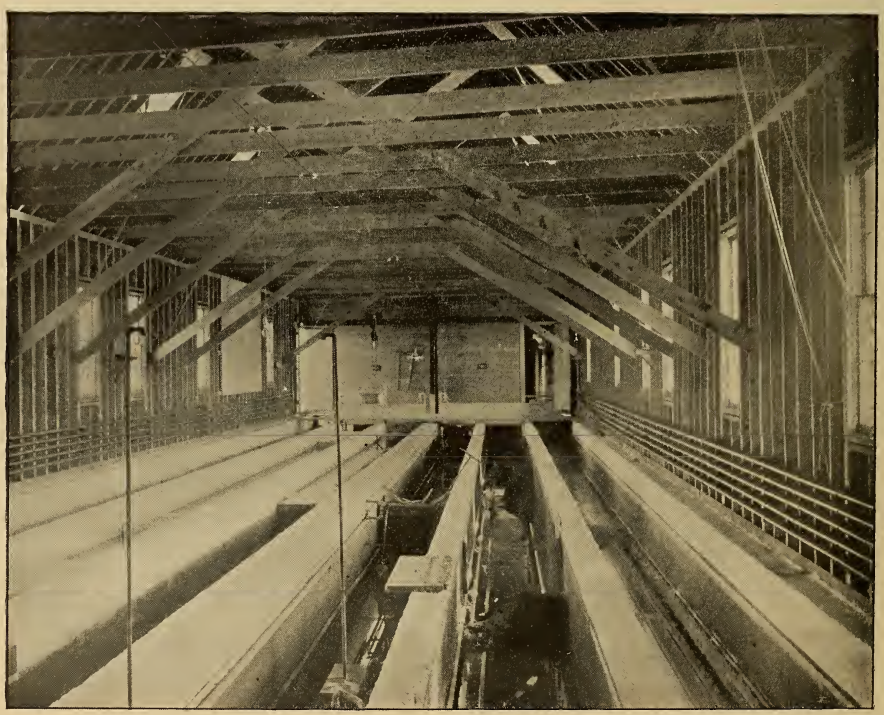
CROSS SECTION OF SEWAGE SETTLING TANKS.

A complete system of under-drainage was designed and executed just as designed. The street plan of Echota, as shown in the illustration on page 313, includes alleys in the rear of the residence lots. Advantage was taken of this fact to separate the lines of drainage conduits, and those of the sewerage system, the latter carrying only house wastes. The principal pipes of the drainage system follow the streets; those to convey sewage are in the alleys. The latter are at a higher elevation than the drain tiles, and, thus, house connections for sewage can be made without danger of disturbance of the drainage system.

The basis of the drainage plan is a

system of tiles of two inches internal diameter, and laid, as a rule, forty feet apart. Their depth is, generally, from four to six feet below the surface. They have open joints, no cement or mortar being used, but around the joints was wrapped a double thickness of cheese cloth. Where strata of quicksand occasionally occurred, the tiles were laid on a board. The exterior of the tiles was octagonal. The minimum gradient of tiles with other lines were made by special Y and T pieces, no cutting of tiles being allowed. The three-inch tiles led, at frequent intervals, to receiving basins in the centre of the streets, and the effluent from these basins is conducted by lines of vitrified pipe to a large masonry well, built near the northwestern angle of the village in connection with the sewage disposal works.

This well is oval in form, 15 feet by

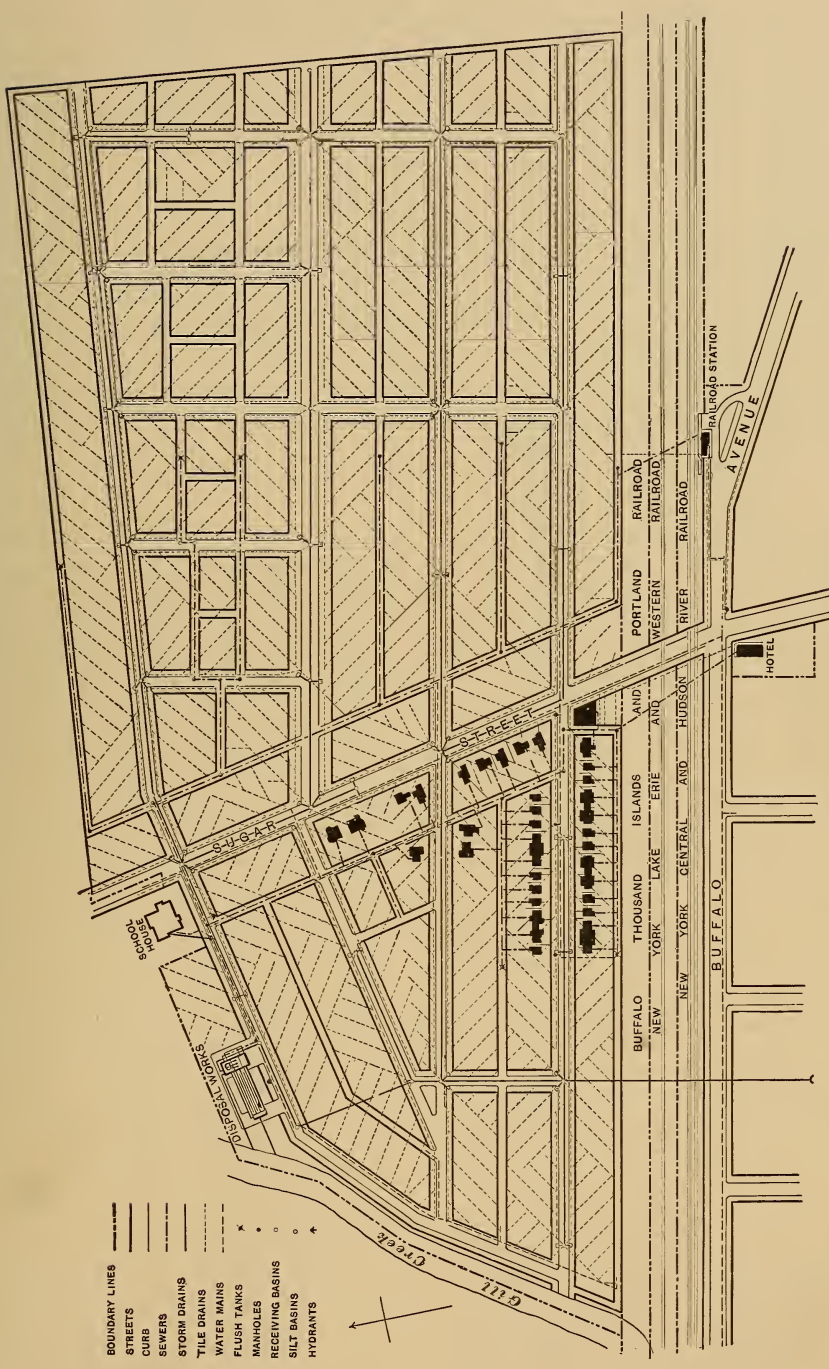


THE INTERIOR OF THE SEWAGE DISPOSAL WORKS.

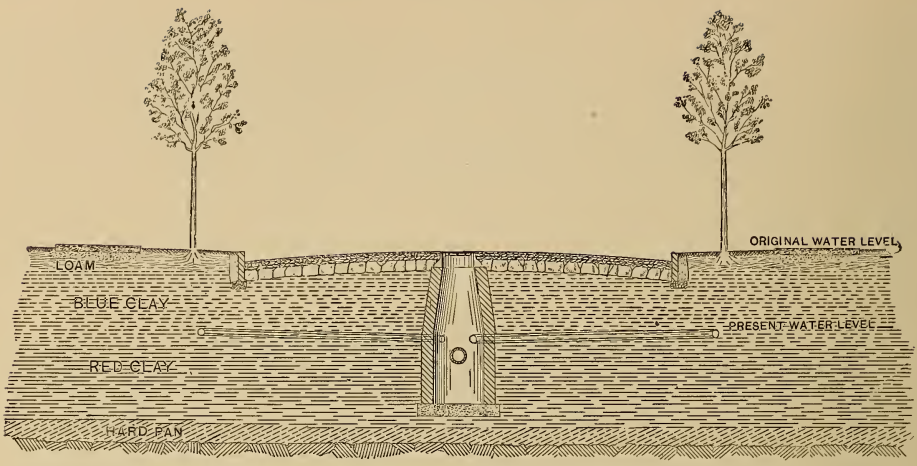
was three-tenths of one per cent. and very great care was taken by the engineers in charge of construction to secure perfect alignment.

The excellent working of the system proves this to have been accomplished. The two-inch tiles deliver into lines of three-inch tiles, laid in the same way and placed, generally, in the streets, under the grass surfaces, but so disposed as to draw the water fully from the ground under and on both sides of the paved parts. All junctions of lines

20 feet in diameter, and of sufficient depth to provide for the suction pipes leading to the pumps. It is divided, by a brick wall, into two compartments, one of which receives the sewage and the other, the drainage water. The latter is pumped directly into the outlet chamber of the disposal works, whence it passes with the purified sewage effluent into the small stream above referred to and, thence, to the Niagara river. The illustration on the opposite page shows, by the fine dotted lines, that the



PLAN OF IMPROVEMENT OF LANDS OF THE NIAGARA DEVELOPMENT CO. AT ECHOTA.

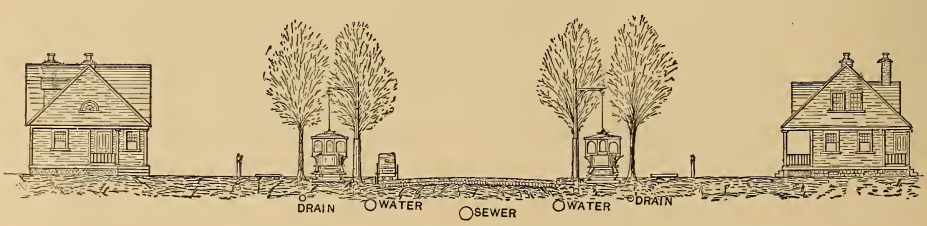


CROSS SECTION OF AN ECHOTA STREET WITH TELFORD-MACADAM PAVEMENT.

whole village is underlaid by this drainage system.

These open jointed small tiles have utterly changed the physical and sanitary conditions of the ground on which the village is built. It is no longer heavy or muddy after rains, neither is it dusty nor dry during the warm season. The hard clay has become friable ; the water of rains sinks quickly into the ground and disappears, grasses flourish, the lawns are in excellent condition, the trees which have been set out are healthy, and the cellars are perfectly dry. In fact, the level of the ground water has been lowered fully four feet, which is virtually, and for all horticultural and sanitary purposes, exactly the same as though the whole surface had been lifted four feet. The place no longer suggests dampness and discomfort, and the difference in the feel of the air is very perceptible to those who have spent much time there before and after the introduction of this drainage.

As every house to be built in the village is to be provided with running water, with closets and with kitchen sinks, a system of sewerage was required which would convey all house wastes quickly and certainly to their ultimate disposal. A separate system was designed, which takes no storm or drainage water. Its conduits are vitrified pipes, with a minimum interior diameter of six inches. These are laid generally in the alleys, at an elevation above the drain tiles. House connections will thus be made without disturbing the street surfaces. The pipes have cemented joints and are automatically flushed at regular periods. They conduct the sewage to one compartment of the well above described. From this well the sewage might be pumped to the small stream near at hand, or through a pipe of proper size, directly



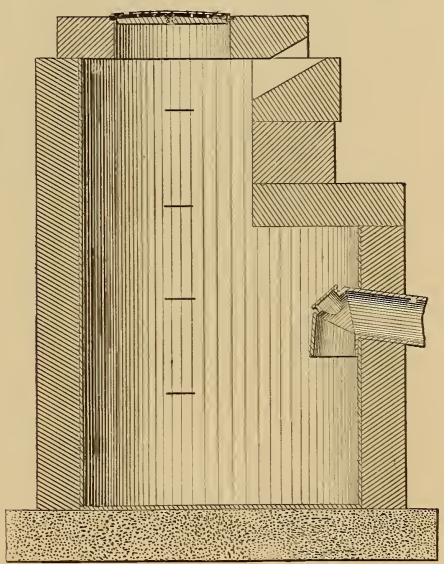
CROSS SECTION OF THE BOULEVARD AT ECHOTA.

into the Niagara river. While the dilution would be great, it was not deemed advisable, nor desirable, to thus deliver untreated sewage into the river, and a system was, therefore, adopted which secures the separation of all solids, the purification of the liquid and the delivery of an effluent deprived of all unsightly and unwholesome characteristics.

This is effected in the sewage disposal works of which the location is seen in the drawing. The details of construction of these works are also illustrated. There is a double set of elongated tanks or deposition chambers, so arranged in section and in length as to ensure a very slow passage of the sewage undergoing treatment. It is pumped from the well directly to the end of one of these elongated chambers, and is there treated automatically, by the action of float valves, with milk of lime and a solution of perchloride of iron.

Sedimentation and precipitation of the solids follow, and any floating substances are intercepted by screens. Chlorine is delivered through perforated pipes supported on brackets near the bottom of the chambers. When a certain quantity of the purified fluid has passed over a weir into the terminal tank, it flows, by syphonage, into the effluent chamber and, thence, with the pure drainage water, pumped from the other compartment of the well, it enters the stream. While one set of tanks is in use, the deposited material is removed by traveling buckets from the other tank, and is used upon the cultivated grounds of the company. The effluent is clear and clean. These works were constructed by Mr. James J. Powers, an expert in the treatment of sewage. The building which shelters the well, the pumps and the disposal tanks is of an exterior construction in harmony with the architecture of the dwellings in the village. This building has also the dynamo for the electric light service of the place.

The occasional sudden engorgement and overflow of the small streams at the site of Echota has been already spoken of. While the system of drainage will take care of all ordinary rainfall, experience on two occasions has given reason to feel that special measures were desirable to prevent the damage and discomfort which might follow the erratic action of these streams. At such times they overflow their banks. But observation has shown that a considerable expanse of country surrounding Echota may then also be under water. An elevation of the bank of the stream immediately adjacent to the village would not suffice.



ONE OF THE CATCH BASINS FOR THE DRAINAGE SYSTEM.

In order to protect the whole area of the improved district, it must be guarded on every side. This has been accomplished by the construction of a bank or dyke along the boundary line and entirely surrounding the village. This dyke is eight feet wide on top, has side slopes of one and a half to one and is compactly built so as to resist the passage of water. On the east boundary of the grounds it is supplemented by a ditch on the outer side, ten feet in width, so placed as to intercept and carry to the Niagara river any volume of water that may come towards Echota

THE SCHOOL AT ECHOTA.

from the higher grounds above. Where the small stream above alluded to is adjacent to the village, the dyke is widened to fifty feet and becomes an exterior street.

As an additional precaution, and especially to prevent any possible damage in the event of a temporary stoppage of the pumps, a relief conduit has been laid to the river, arranged with a check valve so as to open whenever the level of the ground water should rise higher than the water in the river. These combined measures have not only brought the land included within the boundaries of Echota to the satisfactory condition described above, but they have secured them from all danger of overflow.

The study of a design for the ground plan of streets was primarily affected by some existing conditions. The village was bounded on the west by the small stream, on the south by straight lines of railroad and on the north and east by defined property lines. There was one street, sixty-six feet wide, passing through the property, which could not, for legal reasons, be changed. Necessarily accepting these conditions, the plan adopted is shown on page 313.

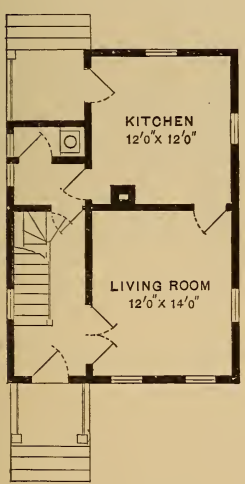
The system of streets and alleys was based mainly on parallelism with the longer side of the village. The streets are, generally, fifty feet in width, but all houses are placed twenty feet back from the street line. The fifty feet street thus becomes virtually ninety feet

wide, giving to each house a front yard and lawn. The lots are, generally, about 115 feet deep, some being still deeper and only a few being 100 feet. There is, thus, ample space for gardens and yards. A system including alleys was adopted after careful consultation on each side of, and outside, the roadway, but near the curb and running between a double line of trees. The houses are to be, uniformly, twenty feet back from the street line, as is shown on page 314.

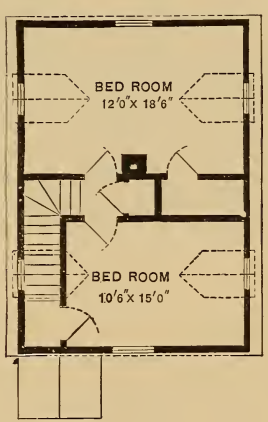
The streets of fifty feet in width have

FRONT ELEVATION.

SIDE ELEVATION.



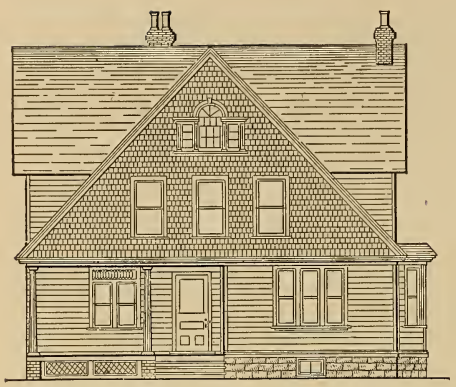
FIRST FLOOR.



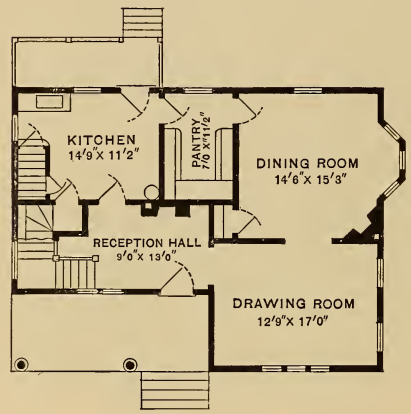
SECOND FLOOR.

ELEVATIONS AND PLANS OF ONE OF THE SMALL HOUSES AT ECHOTA.

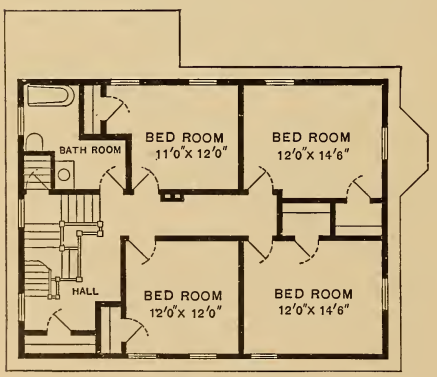
with the officers of the company. Under the strict sanitary regulations which will be made and continued, the objections against alleys, found to exist in some places, will not there obtain. One street, to meet the extension of a proposed boulevard to Buffalo, is 100 feet in width. It has a roadway of forty feet, a provision for electric cars a roadway of twenty-five feet, and a single line of trees on each side. On the drawing of this street there are, incidentally, shown the lines of original water level and of the present level to which it has been lowered. The roadways have a Telford-Macadam pavement. This is formed by bringing the earth to lines parallel with the proposed



FRONT ELEVATION.



FIRST FLOOR.



SECOND FLOOR.

ELEVATION AND PLANS OF ONE OF THE LARGER HOUSES AT ECHOTA.

final surface and the earth is then well compacted by rolling. On this surface is placed the Telford foundation of quarried limestone blocks, eight inches in thickness. Upon these stones is placed a small quantity of sandy binding material, and the surface is rolled smooth. Then follows trap rock broken into pieces not to exceed two inches in size. This is three inches in depth and, with another binding coat on its top, is again well rolled. There is then added another layer, two inches in depth, of trap rock, broken into pieces not to exceed one inch in size. This is rolled, covered with screenings from the broken trap and finally brought to the required lines by thorough rolling, using water during the operation. A steam roller is used for this work.

Maple and elm trees have been set three feet within the lines of curb. The paved surfaces have a crown of four inches in the width of twenty-five feet, and of six inches on the one street, Sugar street, where the pavement is forty-two feet in width. The grades of streets and gutters are necessarily very light, but the lines have been laid so truly that no trouble has been experienced from stoppage of the flow of water. Inlet basins, of which the construction is shown by the sketch on page 315 are placed at the corners of streets and at other points, so that they are never farther apart than 440 feet and generally not more than 300 feet. These receive the water from the street surfaces and gutters and are connected by trapped inlets with the drainage conduits. They have a large depressed chamber below the level of the outlet pipe, in which any solids or street detritus are precipitated by gravity and frequently removed through the cover at the surface.

The same provision of a settling or silt basin, to intercept detritus, is made in the basins receiving drainage from the lines of sub-surface tiles, and wherever more than two lines of tiles met at one point there was placed a silt basin, made of vitrified pipes, fifteen inches in diameter, extending below the inlet and outlet. Connections with

these basins were made by special vitrified pipe with branches to fit the angles of the drains.

All the houses in the village are built by the company. Their architecture combines a general uniformity of design with much variety in form and detail. The architects were Messrs. McKim, Meade & White, of New York. The general appearance of the houses is well indicated in the several illustrations reproduced from photographs. All are painted in the colors adopted by the company,—yellow and white.

ASSEMBLY ROOM, STORE AND HOUSES AT ECHOTA.

Houses for about fifty families have already been built. These vary both in exterior appearance and interior arrangement. One of the simpler and smaller houses and one of the larger and more elaborate ones are illustrated by elevations and plans on pages 317 and 318. The smaller house has four rooms of good size and also a large cellar. It has electric light, running water, closet and kitchen sink. Some of the houses with this ground plan and number of rooms are detached, others are built with either two or four under one roof, but with entirely separate entrances in the front and rear, and each with its own yard and garden space. The larger house has ten rooms, with furnace, bath and other desirable arrangements. The rental for the houses runs from $9 to $30 (£1 16s. to £6) a month and includes, in each case, water and electric light. It is the intention of the company, as soon as the character of the settlement is firmly established, to give its tenants an opportunity to purchase their homes on easy terms, thus avoiding the evils which have at times resulted from the too positive application of the proprietary system. The general appearance of the parts of the village where houses have been built is very pleasing and attractive.

Water, filtered by the Morison & Jewell gravity system, is furnished by the Niagara Falls Water Works Company, one of the allied companies of the power company, and hydrants are placed at convenient distances. Ample provision of hose is made for fire protection. The streets are lighted by incandescent lights of fifty candle power

LOOKING DOWN ONE OF THE STREETS AT ECHOTA.

each. A large building has been placed at one of the prominent street corners. The lower floor is for a general store, and the upper floor has a handsome hall, with dressing and toilet rooms, which is put at the service of the residents of the village. A commodious brick school-house, also, has recently been built at Echota by the city of Niagara Falls.

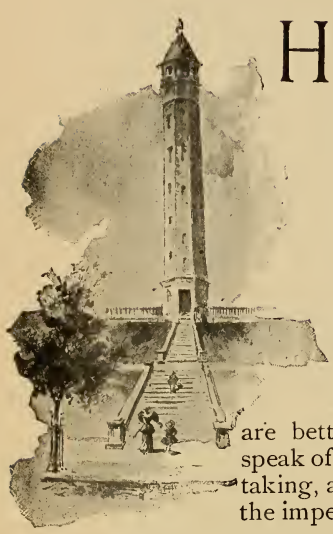
All the works of construction have been continuously in charge of the resident engineer, Mr. W. A. Brackenridge, who has also given many valuable original suggestions, particularly in the development of the protection dykes, the construction of the roads and the arrangement of the houses. The word Echota signifies, in the Indian language, "Place of Refuge." It was suggested as an appropriate name by Mr. Edward D. Adams, the president of the Cataract Construction Company.

Echota is adjacent to the principal lines of railroad, the company having already built a handsome station on the New York Central and Hudson River Railroad. Two principal streets of the city of Niagara Falls run past and through the village, and lines of electric cars are now in operation, connecting with all parts of the city. At the foot of one of the main streets of the village is the wharf from which a daily line of steamers runs to Buffalo.

The village of Echota has, thus, been evolved in accordance with the careful study of the men to whom was committed the responsibility of the solution of a complex problem. A district, not fit for comfortable residence, has been transformed into an ideal, healthful village. Ground upon which no vegetation would thrive has been changed to a region of velvet lawns and blooming gardens. Roads which were a discomfort from dust, or an annoyance from mud, have been made into well-paved, beautiful streets. An unattractive expanse of poor meadowland has become a model town, with inviting residences at very moderate expense for the families of all who may have to do with the busy industries called into action by the wonderful power drawn from the Falls. The prudent foresight of the managers of capital, the artistic design of the architects and the well-matured plans of the engineers have given a result about which the author does not hesitate to write, because that result will have an effective part in the great story of the successful development of the forces of Niagara.

NOTABLE EUROPEAN WATER POWER INSTALLATIONS.

By Col. Th. Turrettini.



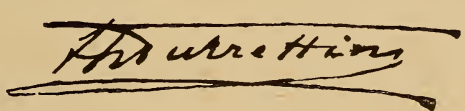
HAVING been invited by the editor to contribute, as consulting engineer to the Cataract Construction Company, an article to this number of CASSIER'S MAGAZINE, it seems proper to say that my English and American colleagues, who are living closer to the great Niagara work, are better able than I to speak of this gigantic undertaking, and to describe how the impetuous Niagara river was mastered and how the wonderful machinery was installed, which, by electric means, will spread light and power far around Niagara Falls.

Leaving, therefore, all account of the Niagara plant to others, I will endeavour to give, for interesting comparison, a description of similar works which have been, or are being, carried out in Europe, more especially the works which the city of Geneva, in Switzerland, is now building and which I have the honour of directing as president of the Geneva municipality and director of its public works.

In comparison with the installation at Niagara Falls even the greatest European works for the utilization of water power are small ; they are to the Niagara works in the proportion of the European to the American continent, in the proportion of the Rhône or the Rhine to the Mississippi and the St. Lawrence.

The town of Schaffhausen, on the Rhine, was the first in Switzerland to endeavour to use the river passing through it to procure power for driving the machinery of the manufacturers in its neighbourhood. Its works were established twenty-one years ago through the generosity of one of its wealthy citizens, M. Moser, who, to endow his native city with this important water power, laid out large sums of money. At that time no other means of transmitting power was known than that of wire ropes, and to that purpose very costly apparatus was set up in the middle of the river, the Rhine being dammed up so as to procure a fall to drive a set of turbines. About 1500 horse-power was obtained in this way and was distributed to neighbouring workshops. The system of wire ropes necessarily limited the development of the works, and the Schaffhausen plant remained as it was when started, until the progress of electrical knowledge allowed of further extension. Three years ago, three new turbines, of 500 horse-power each, were added, driving dynamos which distribute electric power to neighbouring factories.

The example of Schaffhausen was followed a few years later at Bellegarde, on the Rhône. The little town of Bellegarde is situated in France close to the Swiss frontier. There the Rhône, cased in between high cliffs of rock, has pierced for itself a subterranean channel in which it disappears entirely in winter when the waters are low ; for this reason the place is called the "Perte du Rhône." An English company obtained the concession to establish in this place a water-power plant amounting to several thousand horse-power. The company formed a reservoir to receive the waters of the Rhône above the "Perte du Rhône," cut a tunnel in the rock about 1200 meters, or nearly 4000 feet long, and erected a



COL. THEODORE TURRETTINI was one of the members of the International Niagara Falls Commission. He is now president of the municipality of Geneva, Switzerland, and director of its public works.

building for the housing of six turbines of 630 horse-power each, working under a head of water of 14 meters, or about 46 feet. The water-power was used to pump water to the upper level of the town above, and to distribute power in Bellegarde by means of the previously mentioned wire ropes. There, again, the cable transmission was a cause of restraint in the development of the works and several companies succeeded one another without attaining the utilization of all the available power.

In 1878, the town of Zurich established in the Limmat, where it issues from the lake, and in the town itself, works of 1500 horse-power, by the successive setting up of several turbines of 200 horse-power, working under a fall of water varying between 2 and 3 meters, or about 6½ and 10 feet. These remarkable works were constructed under the direction of M. Burkli, then town-engineer of Zurich. The greater part of the power obtained was used for providing water to the town; what remained was distributed to factories for driving small private turbines up to 5 horse-power. Besides this, from about 200 to 400 horse-power could be distributed by wire rope to an industrial quarter in the immediate neighbourhood of the water-works. While the distribution of power through water-pressure was rapidly taken up, the distribution of power through cables proved a failure just as it had been at Schaffhausen and Bellegarde.

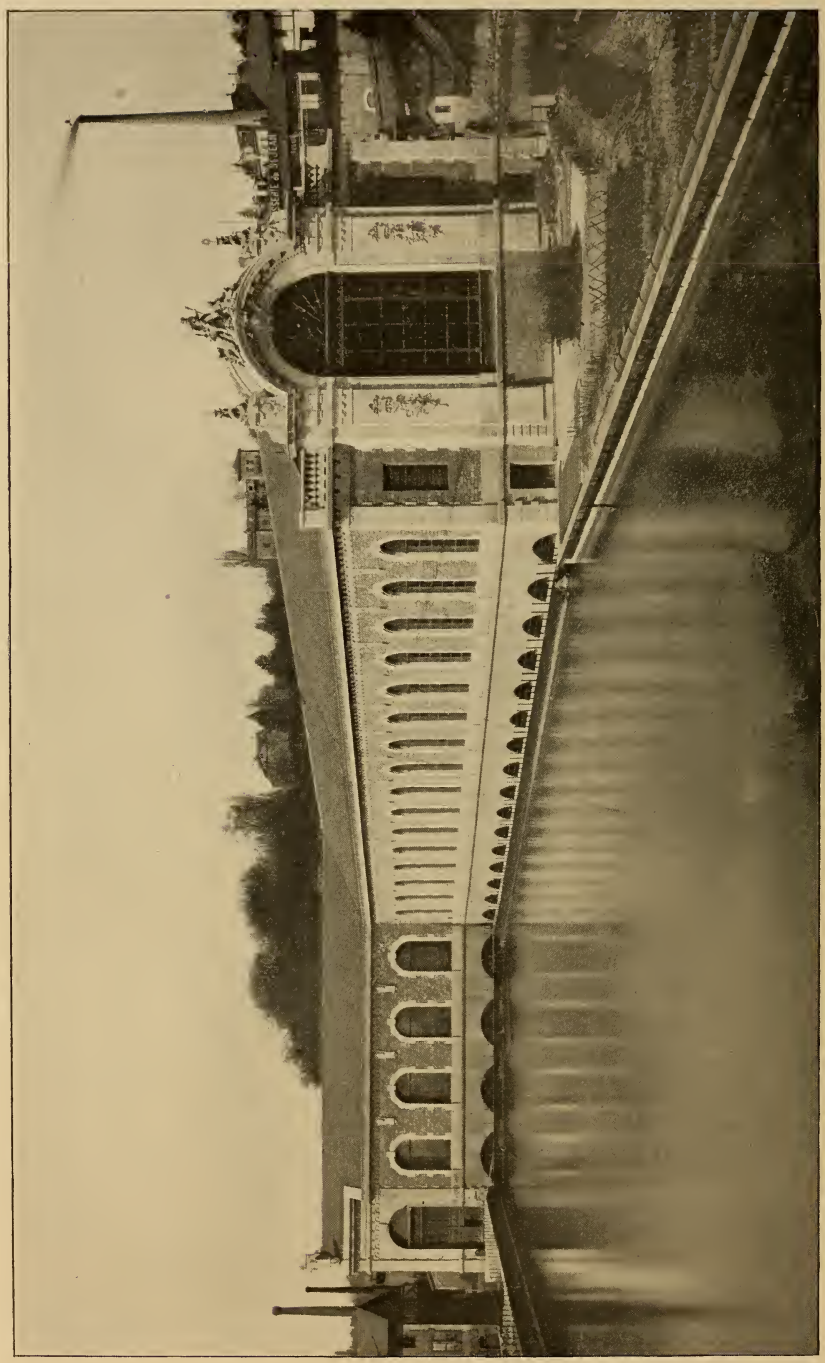
At the same time a company was formed in Fribourg, for utilizing the power of the Sarine in the immediate neighbourhood of the town of Fribourg. There were 1500 horse-power to be disposed of, and the system of transmission was again that of wire rope. The use of this system of transmission was there again a failure, and the company had to be wound up. Several years ago the works were bought up by the Fribourg Government, and electric transmission was introduced. This transformation has given the works a fresh start and they are now doing well.

In 1882, I was elected by my fellow-citizens to the direction of the public works of the town of Geneva in consequence of a paper which I published in support of the idea of utilizing the whole power of the Rhône as it issues from the lake of Geneva and passes through the town. The studies made with that object, and to which several distinguished Swiss engineers contributed, such as Messrs. Merle d'Aubigné, Legler, A. Achard and Prof. Pestalozzi, proved that the Rhône afforded, at Geneva, about 6000 horse-power. The system to be adopted for the distribution of the power was the subject of a special study.

Wire rope transmission of power had been condemned by experience, for it has been amply proved that factories will not come to the source of power, but, on the contrary, that the power must be transmitted to wherever factories are established. Transmission by compressed air gave unsatisfactory results, and transmission by electricity had not, in 1882, reached the degree of perfection which it has attained since then, and could not be thought of.

The only system which remained to be considered was that of water under pressure, and this was the means of transmission which was adopted. Experience has proved that the choice of that system was a good one. The efficiency of water-pressure transmission is not considerable, but this drawback was counterbalanced by numerous advantages, some of which result, it is true, from the special situation of Geneva. The water of the lake, employed for the distribution of the power, is absolutely pure. It could, therefore, be utilized as drinking water, as well as for general industrial purposes and motive power. The same water mains could also be used for town uses and for working private turbines. The water employed, containing no sand in suspension, does not wear out machinery.

The studies preliminary to undertaking the new works were completed at the end of 1883. A credit of two million francs was voted by the Municipal Council of Geneva and the works were begun at once. The plan consisted in



THE 6000 HORSE-POWER STATION AT GENEVA, SWITZERLAND, COMPLETED IN 1886.

THE NEW POWER HOUSE NEAR GENEVA, CONTAINING 15 TURBINES OF 1200 HORSE-POWER EACH.

the setting up of eighteen turbines, of 300 horse-power each, representing a total of 5400 horse-power. The available fall varied between 1.80 meter (about 6 feet) in summer, and 4 meters (about 13 feet) in winter.

The first credit which was voted contemplated the carrying out of all the construction work, dams, buildings, etc., and the establishment of five groups of turbines and pumps. The regulation of the level of the Lake of Geneva formed a part of the new scheme. For more than 200 years constant quarrels had arisen between the inhabitants of the lake shores and the city of Geneva because of a supposed raising of the level of the lake arising from the works carried out in the Geneva estuary, and it was hoped that the carrying out of the new scheme for utilizing the forces of the Rhône would allow an end to be put to these disputes. Geneva obtained 1,100,000 francs from the various States bordering on the lake to carry out, simultaneously with its water-works, a movable dam which would permit keeping the lake always at exactly the same level in all seasons.

The works were actively pushed along and on June 16, 1886, the inauguration festivities took place. Thanks to the system of power distribution adopted, the development was faster than had been anticipated, and to-day, in less than nine years from the starting of the machinery, seventeen turbines, out of the eighteen contemplated, have been erected and the eighteenth is now being constructed. From a financial point of view, the town of Geneva has done well, for, in the year 1894, the works gave a net profit of 2½ per cent. after deducting 3½ per cent. for the interest on the capital and the sinking fund for the wear and tear of machinery.

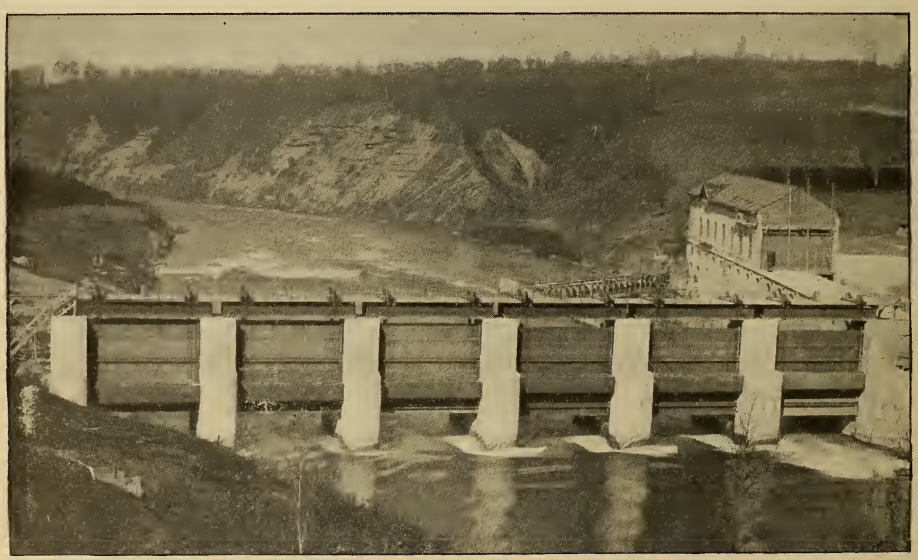
The capital engaged in this undertaking amounted, on December 31, 1894, to 5,500,000 francs. This comprised the cost of the system of water pipes for distribution which, put end to end, would be 140 kilometers, or about 87 miles long.

The success of Geneva in the establishment of water motive power encouraged other towns also to try to make use of the natural water power in their neighbourhood. At Lyons, in France, a company was formed to construct a diverting canal above the city and create a fall of about 8 meters (about 26 feet) at a place called Jonage, about

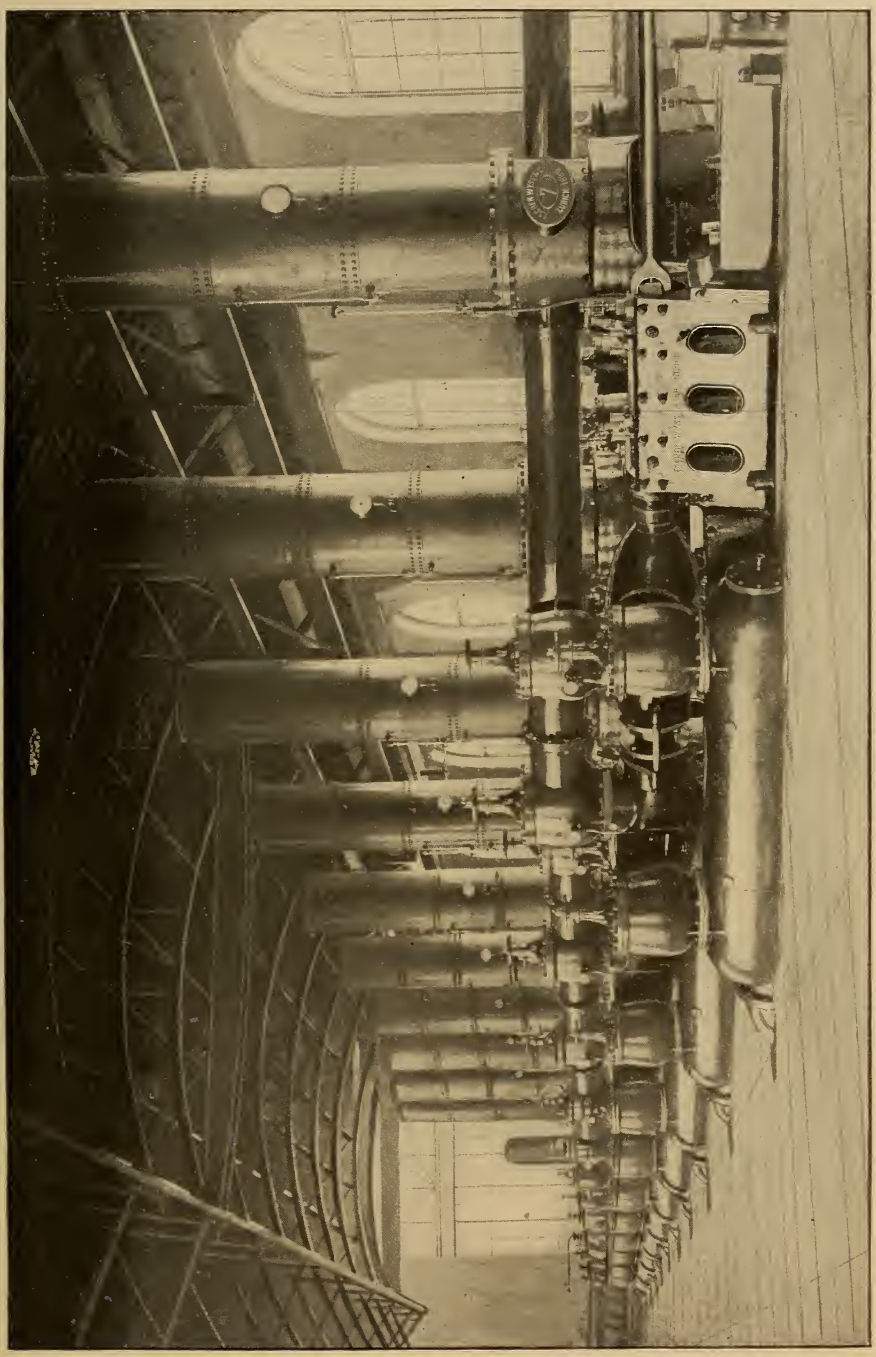
5 kilometers (3 miles) from the city. About 15,000 horse-power is available there and electrical transmission will be employed. The works have just been commenced.

At Rheinfelden on the Rhine, about 15 miles above Basle a company has obtained a concession for 12,000 horse-power, under 4 meters (about 13 feet) fall. The works are to be commenced at once. In the canton of Neuchâtel, the river Reuss, which comes down the Val de Travers, is going to be completely utilized in four successive plants, each to develop 1000 horse-power. This power will supply the wants of the towns of Neuchâtel, Chaux de Fonds and Locle, and also of all the Val de Travers. In the canton of Soleure 3000 horse-power will be obtained in a short time from the river Aar above Soleure and will supply that town and its neighbourhood. On the same river, at Viznau, near Langenthal, the firm of Siemens & Halske is constructing works to obtain about 2000 horse-power and to distribute it in the neighbourhood.

Examples of similar undertakings could be multiplied. The town of Geneva, encouraged by the success of its first venture, decided in 1892 to establish on the Rhône, about 6 kilometers (nearly 4 miles) down stream, new works, very much more powerful than those previously built. A short description of the locality will render the adopted plans clearer. The first works, mentioned above, were situated in the town itself. But, at a point 1500 meters (5000 feet) below the town, the clear blue Rhône receives the river Arve which descends from Mont Blanc. The waters of this river, coming direct from the glacier, are as troubled as those of the Rhône are limpid. Beyond the junction of the two rivers, their waters run side by side, without mixing, for about a kilometer (0.6 mile), forming a blue and a white riband. Thanks to Geneva Lake, the Rhône has a flow of water varying from 120 to 700 cubic meters (4230 to 24,675 cubic feet) per second, whereas the flow of the Arve varies from 20 to 1200 cubic meters (700 to 42,300 cubic feet) per second. Below the junction of the two rivers, the Rhône runs deeply cased in between wild cliffs for several miles, and this has allowed the adoption of a very simple plan for the establishment of the new works.



THE STONEY DAM NEAR GENEVA, BUILT IN 1895.



THE INTERIOR OF THE 6000 HORSE-POWER STATION AT GENEVA.

The place selected for setting up the dam and the buildings for the turbines, called Chèvres, is about 6 kilometers (nearly 4 miles) below the former works. The width of the river, after the erection of the works, will be 130 meters, or about 426 feet. On the left bank, a Stoney movable dam, the same as that adopted for the Manchester canal, in England, allows the raising of the level of the river. The dam, which is 90 meters (295 feet) long, is connected with the right bank by the building containing the turbines. This building is placed in a skew position along the supply channel, and, in connection with the Stoney dam, forms a complete dam across the river.

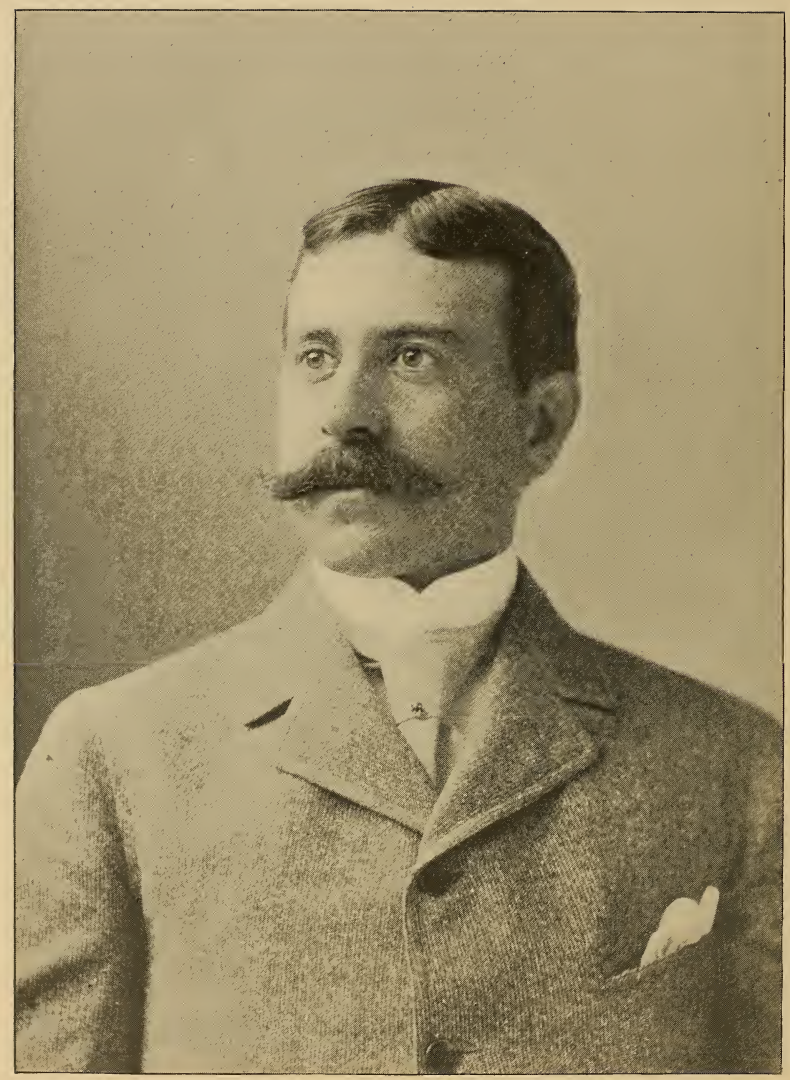
The dam has six openings, each 10 meters (about 33 feet) wide. Each opening can be closed ad libitum by a sluice, 8 meters (about 26 feet) high. The sluices are in one piece, hung with counterweights, and slide on rollers. Thanks to this, they are easily lifted or let down by two men, in spite of the enormous pressure of water which they bear. The fall produced by the dam varies with the seasons. It is 8 meters, or about 26 feet, high in winter, and diminishes to 4.50 meters, or about 15 feet, in summer.

The building for the turbines is 150 meters (492 feet) long and will eventually contain 15 turbines of 1200 horse-power each. To obtain a sufficient velocity for directly working the dynamos which they set in motion, each turbine is composed really of two turbines of 600 horse-power, placed one above the other on the same shaft. In winter, when the fall is highest, the lower turbine alone is open ; in summer, when the fall is less, the two turbines work simultaneously. The wheels were constructed by the Messrs. Escher, Wyss & Co., of Zurich.

The dynamos, constructed by the Compagnie de l'Industrie Electrique de Genève, are on the two-phase system. Each turbine-shaft carries two dynamos of 600 horse power. The teeth of one of the wheels are displaced by a quarter of the pitch with respect to those of the other wheel and each has a separate exciting current so as to be able to vary the load of each machine without inconvenience. The weight of each dynamo is about 70,000 kilog., or about 154,000 lbs.

The armature is fixed, and the revolving part, weighing 16,000 kilogs., or about 35,200 lbs., contains no wire and is only a mass of revolving steel. The speed of rotation is 80 revolutions per minute. All the dynamos may be coupled in parallel. The aerial transmission, 6 kilometers, about 3¾ miles, long, mounted on iron posts, is composed of return wires concentric with the outgoing wires, so as to reduce induction as much as possible. The transmission for light will be independent of the power transmission. The tension is 2400 volts.

These new works of the town of Geneva, which will make another 18,000 horse-power available, are nearly completed. The first three turbines are being erected and the dynamos are ready, so that the machines will be started during this summer. The works have been carried out under my direction by M. Butticaz, chief engineer of the Geneva water and water-power works. They will be the most important in existence after those at Niagara Falls, but they are very far from rivalling them. My purpose in writing these lines has been to furnish a point of comparison which would allow one to gauge the immense advantages of the gigantic instrument which American industry now possesses.



S. Dana Greene

S. DANA GREENE is a U. S. Naval Academy graduate, and resigned from the Navy in 1887 to become assistant, and later, chief engineer of one of the prominent electric establishments. He is now assistant general manager of the General Electric Company.

WINTER AT THE FALLS.

DISTRIBUTION OF THE ELECTRICAL ENERGY FROM NIAGARA FALLS.

By S. Dana Greene, Electrical Engineer.

THE utilization of at least a portion of the enormous amount of energy which, in the parlance of this practical age, "runs to waste" annually over the Falls of Niagara, has been written and talked of, studied and suggested, for the past hundred years. It has been reserved, however, for those of us who will see the nineteenth century rounded out and the twentieth ushered in, to witness the practical accomplishment of this great undertaking.

Other articles in this magazine tell of the engineering skill, perseverance and ingenuity which, combined, have helped to bring about the harnessing of Niagara. It is the purpose of this article to point out some of the applications to which the electric energy generated at the Falls has already been put, and to discuss other applications which suggest themselves as probabilities or possibilities. These applications can be broadly divided into two classes: (1) Those which are undertaken near the generating station, within a radius of, say, ten miles. (2) Those which necessitate a transmission of the power for a distance of more than ten miles before it is utilized.

The first class offers a tempting field to those practical men who prefer present certainties to future possibilities; while the second class presents an array of scientific problems, and of theoretical and empirical studies and calculations which are attracting the attention of the whole engineering world. Time alone can tell how many of these problems will be solved, and how far practical results will verify the theoretical figures. We may, however, assume with reasonable certainty, that as the science of electricity, which is yet young, advances from year to year, the area of

THE ELECTRIC PLANT OF THE PITTSBURGH REDUCTION COMPANY AT NIAGARA.

influence of the Niagara power will be constantly extended, until that historic and picturesque spot becomes a true electrical Mecca. When this result shall have been accomplished, the far-seeing business sagacity and engineering talent of those who have launched the present enterprise will bear their fruit, while the capitalists who have boldly invested their millions will have their proper reward in a handsome and ever-increasing return on their investment.

Before discussing in detail the two classes of application already mentioned, it is well to glance at some of the broader questions involved. The electric motor is already well-known as a piece of commercial apparatus. Thousands of them are in daily use, having displaced steam and gas engines and other forms of power motors. It is compact, easily cared for, very reliable, and, with a continuous rotary motion, it can be applied to its work with a minimum of expense and complication. For reliability, simplicity and certainty of operation, it stands without a peer in the motor field. It follows, as a matter of business, that industrial power consumers can, with profit, substitute the electric motor for that which they now use, provided the electric power can be delivered to the motor at a cost less than that now paid for other power, including the cost of operating and maintaining the motor.

Such a change of motive power has been, as a matter of fact, progressing actively for the past five years, especially in the larger cities, where a network of wires, either overhead or underground, has gradually covered the territory like a system of gas or water pipes, ready to be tapped for any consumer who desires to use the electric power. The extent to which the change has been effected is not generally realized. Thus in New York, it is estimated that not less than 8000 horse-power in electric motors are at present in use, the motors varying in size from ⅛ horse-power to 100 horse-power; in Brooklyn about 4000 horse-power are employed, while 25,000 horse-power additional in motors are used in that city for electric traction purposes.

In many large industrial manufacturing establishments it has been found economical to generate electric power in a central power station, and then distribute it throughout the various shops, electric motors being utilized to operate the lines of shafting, heavy tools, cranes, rolling mills, etc. In all of these applications, the reason for the change in power is found, first, in the ease and economy with which the elec-

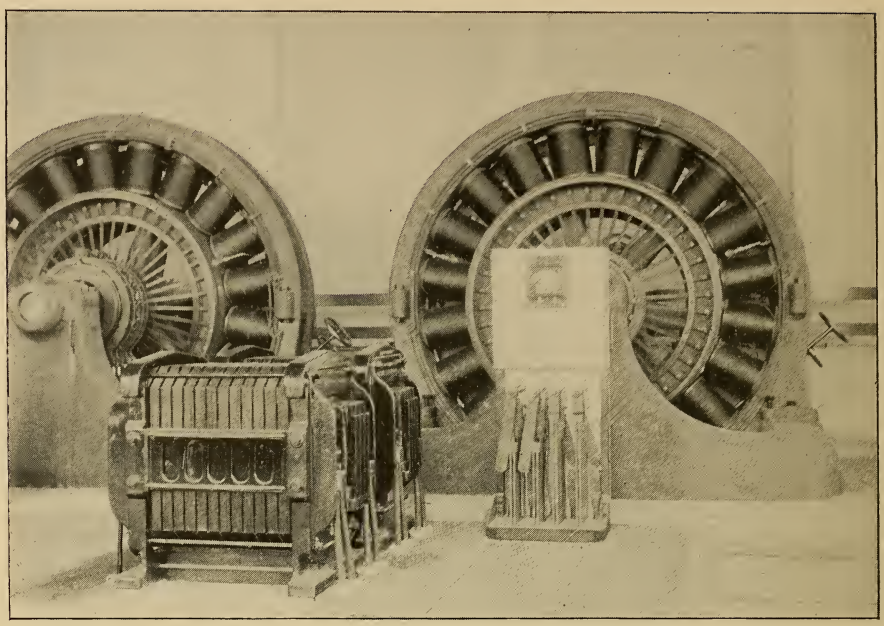
tric power can be transmitted; and, second, in the high efficiency and low cost of maintenance of the electric motor. Although additional conversions of energy are involved, these conversions are accomplished in large units,

In addition, electricity has a large, and ever widening field in lighting, heating and cooking; in plating and electrotyping; in the smelting and reduction of refractory ores; and in surgical and medical work. It is, in fact,

DIRECT-CURRENT SIDE OF THE ROTARY CONVERTERS AND THE LOW-TENSION SWITCHBOARDS.

under the most economical conditions, so that there is an actual and very important saving to an establishment using electric power throughout, instead of steam, or compressed air, or rope transmission.

becoming more and more a part and parcel of our every-day practical requirements, while in the language of the patent office, "new and useful" applications are in daily process of invention and development.



TWO OF THE ROTARY CONVERTERS AND ALSO TWO OF THE STATIC TRANSFORMERS IN THE PITTSBURGH REDUCTION COMPANY'S PLANT.

With such a field of usefulness for electric power, and with the assurance of the best technical advice attainable that the work was feasible from an engineering standpoint, and that the cost was not at all prohibitive, one can realize why it has been possible to secure capital for the Niagara power plant; and as the present power house stands ready to deliver fifteen thousand horse-power in electrical energy, with an ultimate capacity of fifty thousand horse-power (the intake canal being large enough to supply two power houses of this capacity), we can consider the near-by applications of power about to be made.

The Niagara Falls Power Company owns somewhat more than a square mile of land around the power house, and it purposes to rent or sell this land to industrial establishments desiring to locate there, and to sell them electrical power, available for twenty-four hours a day, every day in the year, at a price so low that these establishments can afford to move from their present locations and sell their present plants.

The power, as generated, is an alternating two-phase current of twenty-five cycles per second, or three thousand alternations per minute, the electromotive force, or electrical pressure, being about two thousand volts. At this voltage, and with the short distances involved in local distribution, the transmission involves no engineering difficulties, electrical or otherwise; in fact, it is similar to many such transmissions in various cities and towns. Many inquiries have been received from all parts of the country asking for information as to the character and cost of the power service, the amount of power available, etc.

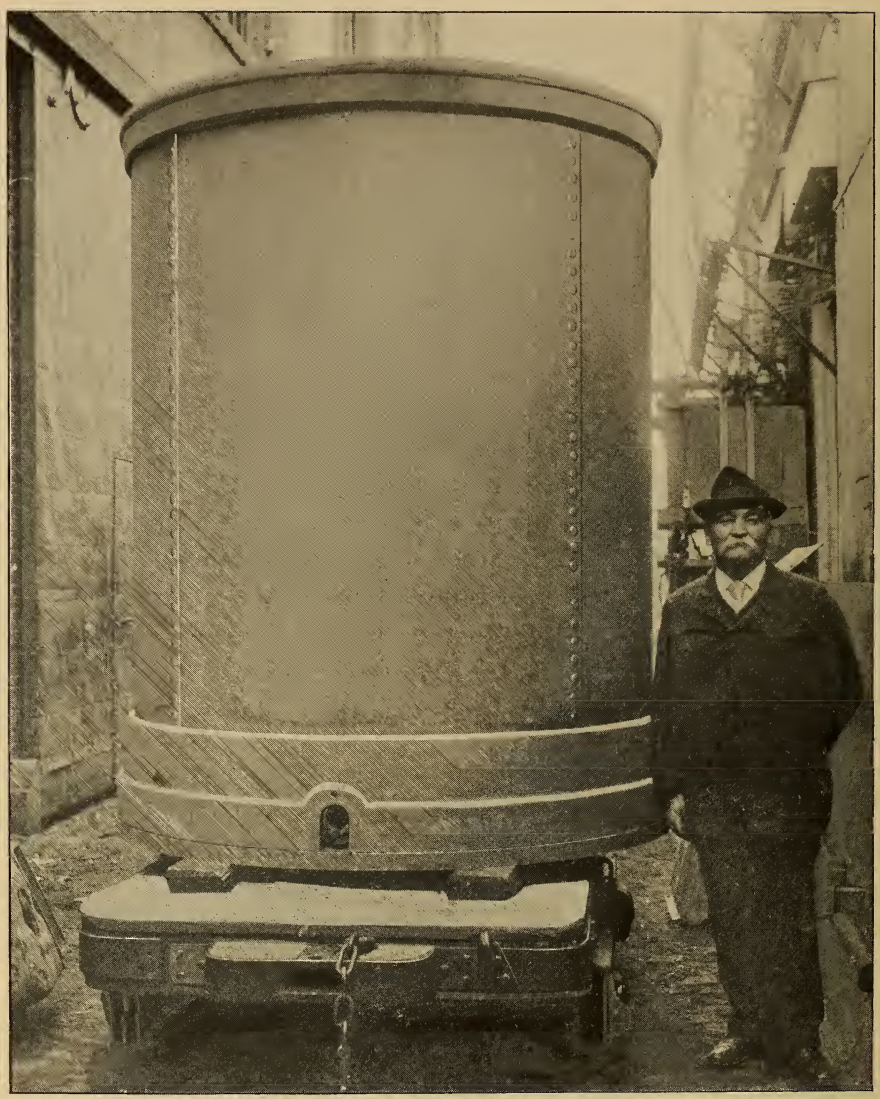
Two manufacturing establishments have already closed contracts, erected new plants on the ground, and are about ready to start operations, viz.: the Pittsburgh Reduction Company, of Pittsburgh, manufacturers of aluminium, requiring 2000 horse-power; and the Carborundum Company, also of Pittsburgh, manufacturers of carborundum, a variety of emery, requiring 1000 horse-power. As each of these companies will utilize

the electric current for a special purpose, each differing entirely from the other, a brief description of the two plants will be of interest.

The Pittsburgh Reduction Company produces pure aluminium,—a metal which is beginning to attract favourable attention—from alumina, an oxide of aluminium, by smelting the latter with the proper flux, in carbon-lined retorts or crucibles, the mass being liquefied and the aluminium reduced by an electric current, passing from a series of carbon rods suspended over the top of the crucible and forming one pole of the circuit, to the carbon lining at the bottom of the crucible which forms the other pole. The current required is what is commonly called a direct current, the voltage, or pressure, at the terminals in the reducing room being maintained constant at 160 volts, and about 60 retorts being placed around the room in series with one another.

As the current, delivered to the Pittsburgh Reduction Company by the power company, is of the two-phase variety, alternating, at 2000 volts pressure, it is necessary to reduce this pressure and then transform the current from alternating to direct. The first change is accomplished by passing the current through large "static transformers," built on the principle of the Rhumkorff coil, by which the voltage is reduced from 2000 to 115. The current is then passed through a "rotary converter," where it is changed from a two-phase alternating current at 115 volts to a direct, or continuous, current at 160 volts. The rotary converter is a direct-current generator, with the addition of proper collecting rings and connections on the rear of the armature, by which the alternating current is led into the machine. It may be considered, in fact, as a motor and generator in one machine. The illustrations on pages 334 to 337 show the power room of the Pittsburgh Reduction Company's plant, with the apparatus installed and ready to operate. The plant has a capacity, on the direct-current side, of 10,000 ampères at 160

THE ALTERNATING CURRENT SIDE OF THE ROTARY CONVERTERS, THE ALTERNATING CURRENT SWITCHBOARDS AND THE STATIC TRANSFORMERS.



ONE THOUSAND HORSE-POWER STATIC TRANSFORMER AT THE WORKS OF THE CARBORUNDUM COMPANY. BUILT BY THE GENERAL ELECTRIC CO. NEW YORK.

volts, or 1600 kilowatts,* or about 2000 electrical horse-power.

The Carborundum Company utilizes electricity in a different way. A large core of carbon, about 8 feet high and a square foot in cross section, is placed vertically in a large smelting furnace, and around this core is packed the carborundum ore. An alternating electric current is then passed through the core from end to end, the core being gradually brought to an intense (white) heat. This heat is kept up for about twelve hours, the carborundum being gradually reduced from the ore, in crystalline form.

The crystals are taken from the furnace, ground to a powder and pressed and moulded in various forms for use as emery. The Carborundum plant

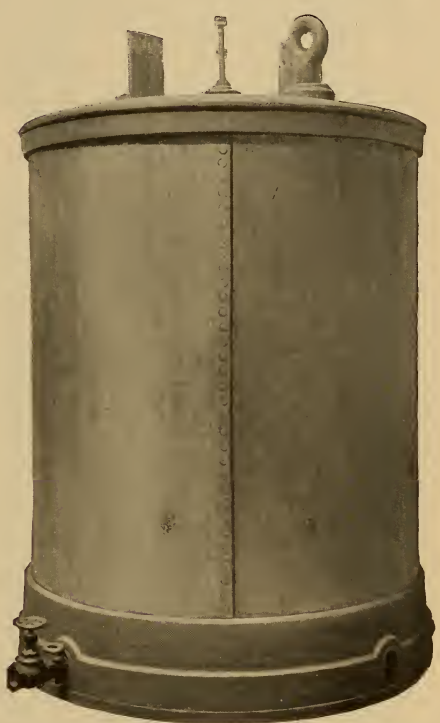
* A kilowatt (one thousand watts) is the electrical unit of power. An electrical horse-power, 746 watts, is about ¾ of a kilowatt.

consists of a 1000 horse-power static transformer, by which the voltage is reduced from 2000 to 100 and 200 volts, and a special regulator of about the same size, by which the voltage at the core of the furnace is varied as the resistance of the core changes, owing to its change of temperature, the current being maintained about constant. The illustrations on pages 338 to 341 and on page 348, show this apparatus in completed form. The Carborundum plant is unique, both on account of the way in which the electric power is utilized and also on account of the size of the static transformer and regulator, which are the largest pieces of apparatus of the kind ever built.

Static transformers of the size used in these two installations (270 horse-power and 1000 horse-power respectively) require some artificial method of cooling, for, notwithstanding the fact that the transformers have an efficiency of from 97 to 98 per cent., the energy transformed into heat is, nevertheless, so great that there is not sufficient radiating surface to carry it off, and the temperature at full load would soon rise to such a point as to endanger, if not destroy, the apparatus. Two different plans of cooling have been adopted. In the Pittsburgh reduction transformers a blast of air is forced constantly through the numerous interstices between the coils, from below, and the heat is thus easily controlled.

The Carborundum transformer is cooled by a continuous circulation of oil. The transformer is placed in a cylindrical iron case, standing on a ring about 6 inches high from the bottom of the case. Oil is forced into the transformer from the bottom, and up through its interstices, until it flows over the top and into the surrounding case. It is then drawn off, passed through a cooling coil surrounded by running water and is again forced through the transformer. The resulting decrease in the temperature rise is the same as in the case of the air blast. In either case the amount of power required for the air blast or for the oil circulation is very small—less than ½ per cent. of the capacity of the transformer.

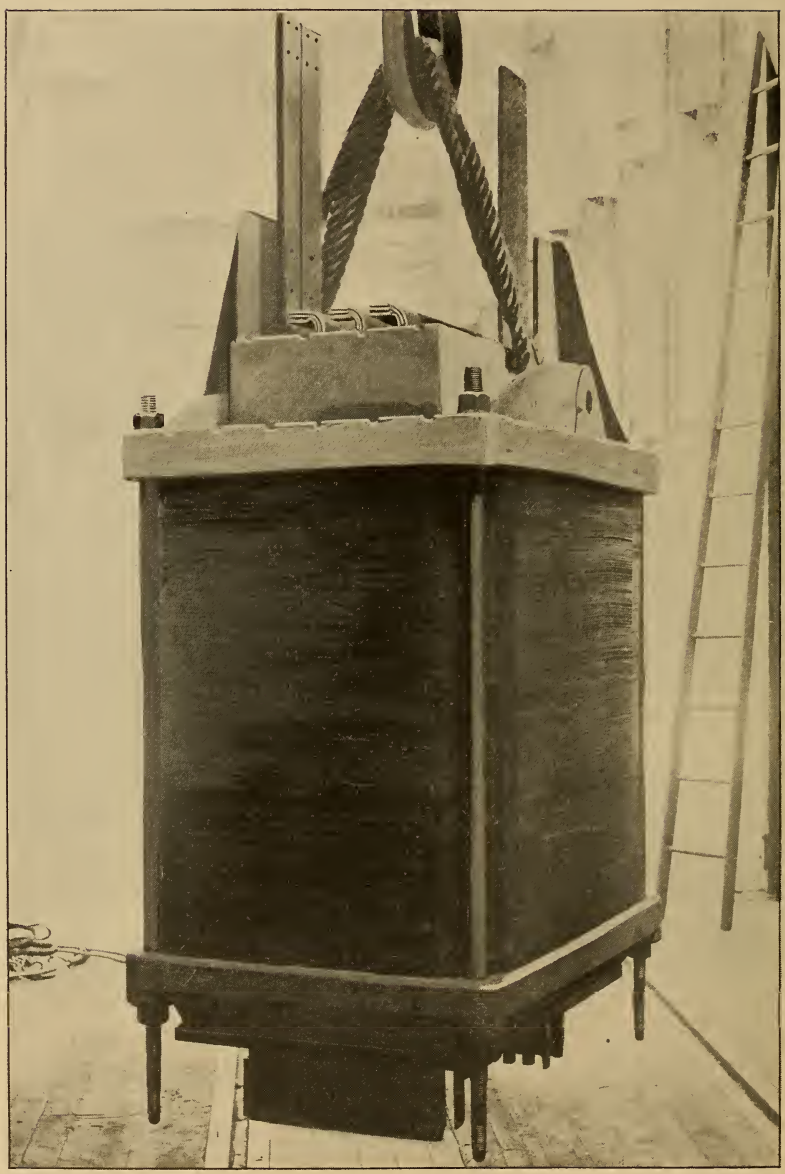
Another application about to be made of the power is the operation of the electric road at Niagara Falls, and also of that now being pushed to completion, as a rapid transit line, between Buffalo and the Falls. About 1500



ANOTHER VIEW OF THE STATIC TRANSFORMER.

horse-power in rotary converters will be required for this work, in 500 horse-power units, transforming the alternating into direct or continuous current at 500 volts. The electric lighting station and the water works at the Falls will probably also utilize the power at an early date.

With nearly 5000 horse-power contracted for locally, and with the probable demands in the near future for other new plants, as well as for extensions to those already installed, it is reasonably certain that from 10,000 to 15,000 horse-power will be required in a year to supply the demands of consumers within a radius of three miles

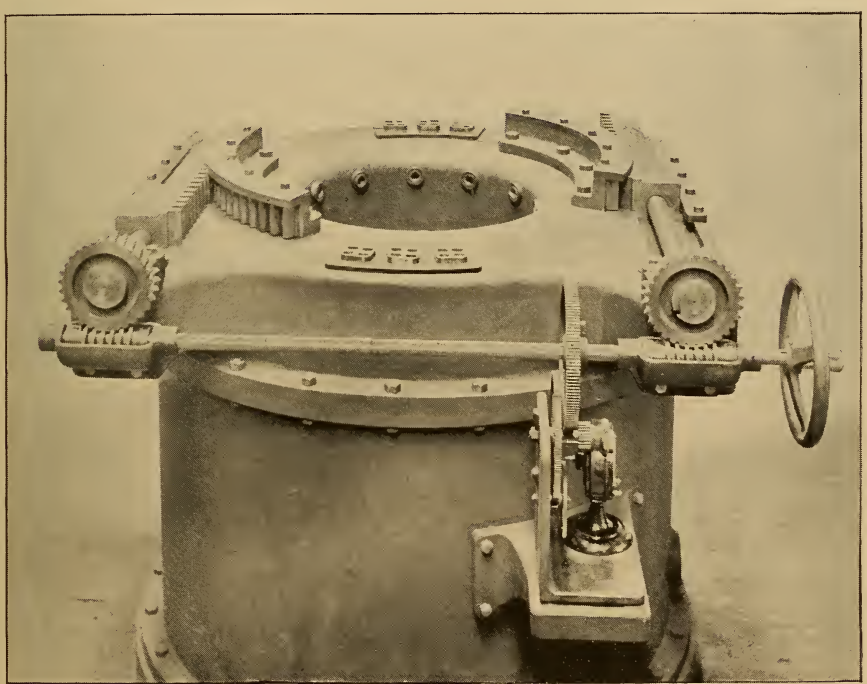


THE INTERNAL MAKE-UP OF THE CARBORUNDUM CO.'S LARGE STATIC TRANSFORMER. THIS TRANSFORMER REDUCES THE PRESSURE OF THE TWO-PHASE ALTERNATING CURRENT FROM 2400 TO 200 VOLTS.

of the power station. Between Niagara Falls and Tonawanda—a distance of about ten miles—is an open, farming country, which is already being bought up for the purpose of cutting it up for manufacturing sites. Tonawanda itself, which may be considered within the radius of what has been classed as "near-by distribution," has special advantages as a manufacturing centre.

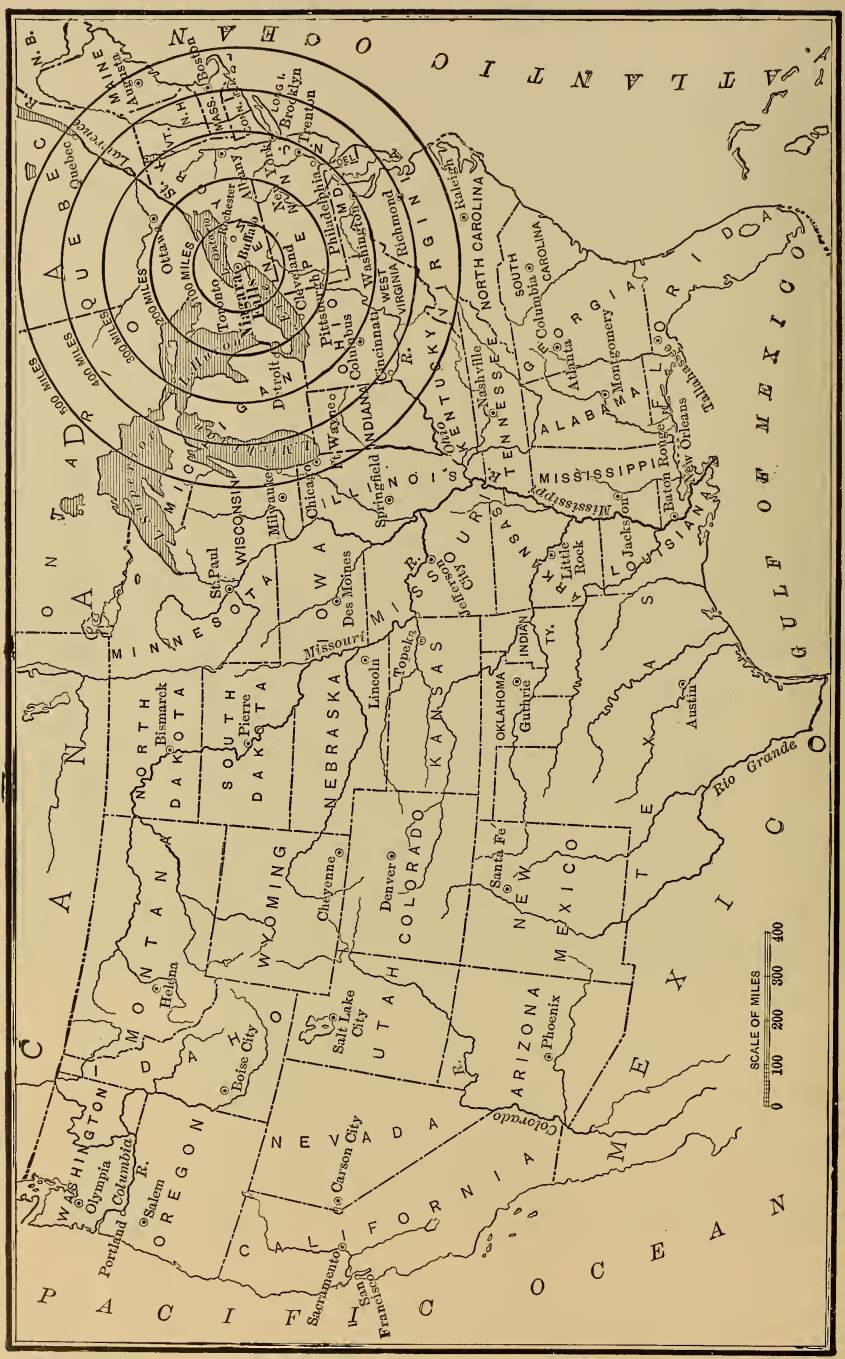
Ten thousand additional horse-power is a reasonable estimate of the power that will be utilized in this territory, so that it seems fair to predict that in five years, with moderately prosperous business conditions, the "near-by" consumers of power will aggregate about 25,000 horse-power. This power will be distributed and used on the general lines already developed in other places, except that the individual consumers will be larger users. No radically new electrical engineering problems are involved, and the cost of distribution will be relatively small. The consumers will reap the benefit of very cheap power, available at any hour, day or night, while the Power Company will be assured of a definite revenue, without the large expenditure necessary for heavy transmission lines and their accessories.

The applications of power thus far suggested or discussed are such as come substantially within the present stage of electrical development, and have little about them, therefore, to cause distrust of their successful outcome, financially or otherwise, even in the minds of those who have given no special attention either to the rapid growth of the electrical art in general or to the development of this great power plant in particular.



THE CARBORUNDUM COMPANY'S ONE THOUSAND HORSE-POWER CURRENT REGULATOR.

We come now to the second and larger phase of the subject—the transmission of the power from Niagara to Buffalo and points beyond, where, in order that its sale may be rendered the more profitable by reason of the quan-



MAP OF THE UNITED STATES, SHOWING THE COMMERCIAL POSSIBILITIES OF NIAGARA POWER.

PUTTING DOWN CABLE CONDUITS AT NIAGARA.

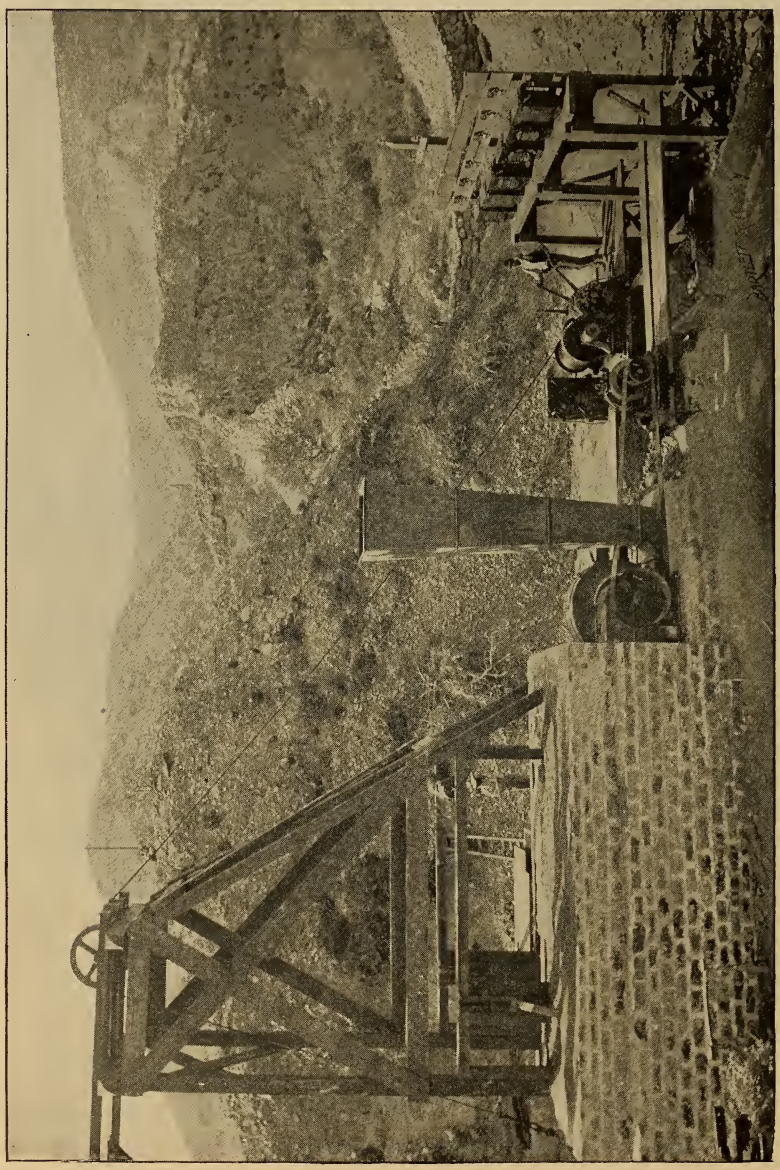
tity consumed, it must successfully displace existing power plants of all descriptions, including even the local electric lighting and railway plants at present operated by steam, and must establish and prove its claim of superior economy and of equal or superior reliability and continuity of service. It is the solution of this problem that demands the attention of electrical engineers, and the results will determine whether the present power house at Niagara, with its ultimate capacity of 50,000 horse-power, shall be only the beginning or the end of the enterprise.

It is instructive to study the map and consider the geographical and commercial possibilities of different areas of distribution, with Niagara as a centre. From this point, on the map shown opposite this page, circles have been drawn with radii of 100, 200, 300, 400 and 500 miles. Table I. gives interesting data of several areas so circumscribed, including areas with the smaller radii of 25, 50 and 75 miles.

TABLE I.

Radius in Miles.	Approximate Area in Square Miles (United States Only).	Number of Cities Within this Area of 5000 People or More	Population of Same (Census 1890)	Approximate Estimate of Horse-Power at Present Used in these Cities.
25	960	4	282,806	69,000
50	2,900	7	305,000	76,750
75	6,300	10	470,000	111,700
100	11,500	16	543,000	143,700
150	27,700	34	825,000	261,500
200	55,500	69	1,756,000	521,000
300	196 000	198	8,246,000	1,967,000
400	272,000	342	11,150,000	2,733,000

About one-fifth of the population of the United States is included within a radius of 400 miles from Niagara. The conditions controlling the commercial delivery of power to a point within any of the areas given depend upon the answers to the following questions:



AN ELECTRIC HOISTING PLANT AT BOLEO, MEXICO.

1. What amount of power can be sold, provided it is delivered? That is, what are the local demands?

2. Are the transmission and delivery to the desired points practicable from an engineering standpoint?

3. If the power can be delivered successfully, can it be sold by the Power Company at such a figure as to compete with the price of power generated locally; that is, compete with the large and economical local power plants, such as electric light and railway stations and city water works, as well as with the small and comparatively wasteful users? The latter class of power consumers are, of course, much more numerous in point of numbers, but not necessarily so in point of amount of power consumed throughout the twenty-four hours.

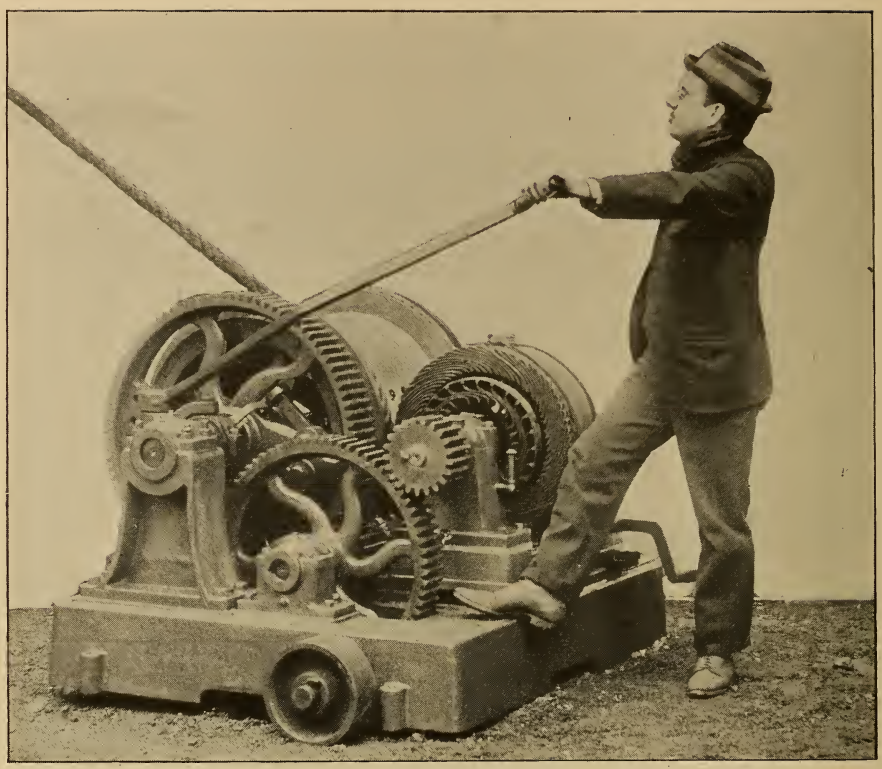
The first question can be answered only by a local investigation and canvass of the power users, their present consumption and the probable annual growth of this consumption. This latter point is of importance, for the transmission line and transformer stations should be built so as to provide for reasonable growth in demands for a period of from five to ten years. It should not be necessary to erect new buildings, nor to provide new pole lines or conduits for this growth; they should be built of such a capacity as to make it necessary only to install additional apparatus or additional copper wire in the stations or on the pole lines originally provided. The following table gives an idea of the demands for power in some of the principal cities included in Table I. on page 343.

TABLE II.

City.	Population, Census 1890.	Distance by Wire from Niagara Falls to City Limits.	Estimated Horse-Power Used.
Buffalo, N. Y.	256,000	15	30,000
Rochester, N. Y.	134,000	78	25,000
Erie, Pa.	41,000	113	8,000
Ashtabula, O.	84,000	150	5,000
Syracuse, N. Y.	88,000	152	20,000
Utica, N. Y.	44,000	203	7,000
Cleveland, O.	261,000	213	45,000
Pittsburgh, Pa.	239 000	240	65,000
Akron, O.	28,000	253	5,000
Schenectady, N. Y.	20,000	281	8,000
Sandusky, O.	18,500	281	5,000
Albany, N. Y.	95,000	309	15,000
Total	------	---	238,000

The second question, regarding the engineering possibilities, is a vital one, and demands careful consideration. Apart from engineering problems pure and simple, it is to be remembered that the transmission line to any of the points mentioned in Table I. must pass through

CROSS SECTION OF A CABLE CONDUIT.



AN ALTERNATING CURRENT INDUCTION MOTOR, GEARED TO A HOIST.

a more or less populous country, and if the necessary voltage or pressure of the current is so high, or if the pole lines and conductors must be of such a size and so placed, that the insulation of the line cannot be maintained, or danger to human life cannot be avoided by any reasonable precaution, then the transmission cannot be considered practicable commercially.

Precedents are always of value in studying the solutions of engineering problems, and it is interesting to consider briefly two remarkable long-distance transmissions of power in successful operation in the United States, although neither are electric transmissions, and each differs materially from the other. One is the transmission of oil by pipe-line, from the natural oil fields of New York, Ohio and Pennsylvania, to tide-water, a distance of over 400 miles. The other is the transmission of natural gas, also by pipe-line, from the Indiana fields to the city of Chicago, a distance of about 120 miles.

The piping of oil, first from the individual oil wells to storage centres, and then from these storage centres to tide-water, has been a process of gradual development for the last thirty years. The necessity for what may be called the "collecting system" of pipes was felt shortly after the discovery of the natural oil wells, and arose from the rough and mountainous character of the oil country, which made the question of transportation an exceedingly difficult one. The individual wells were gradually connected by feed pipes to larger trunk lines, which carry the oil to the storage centres.

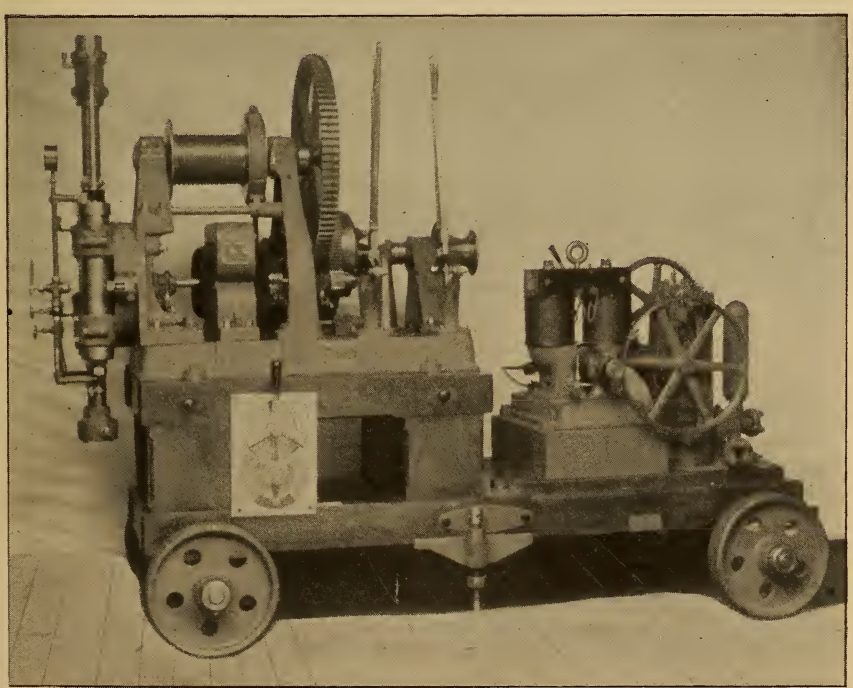
The largest of these centres is at Olean, N.Y., about seventy-five miles from Buffalo. There the Standard Oil Company have large storage tanks, with

an aggregate capacity of nearly 9,000,000 barrels of oil, and from this point starts the great trunk line, composed of three 6-inch wrought iron pipes, running to tide-water in New York harbor, where the oil is loaded into tank steamers and shipped all over the world. There are twelve pumping stations along this trunk line, situated about 35 miles apart, and both the pumps, the pipe-lines and the subsidiary fittings are marvels of mechanical ingenuity and perfection. The pumps operate at a pressure of about 1000 pounds per square inch, and the capacity of the line is about 30,000 barrels a day.

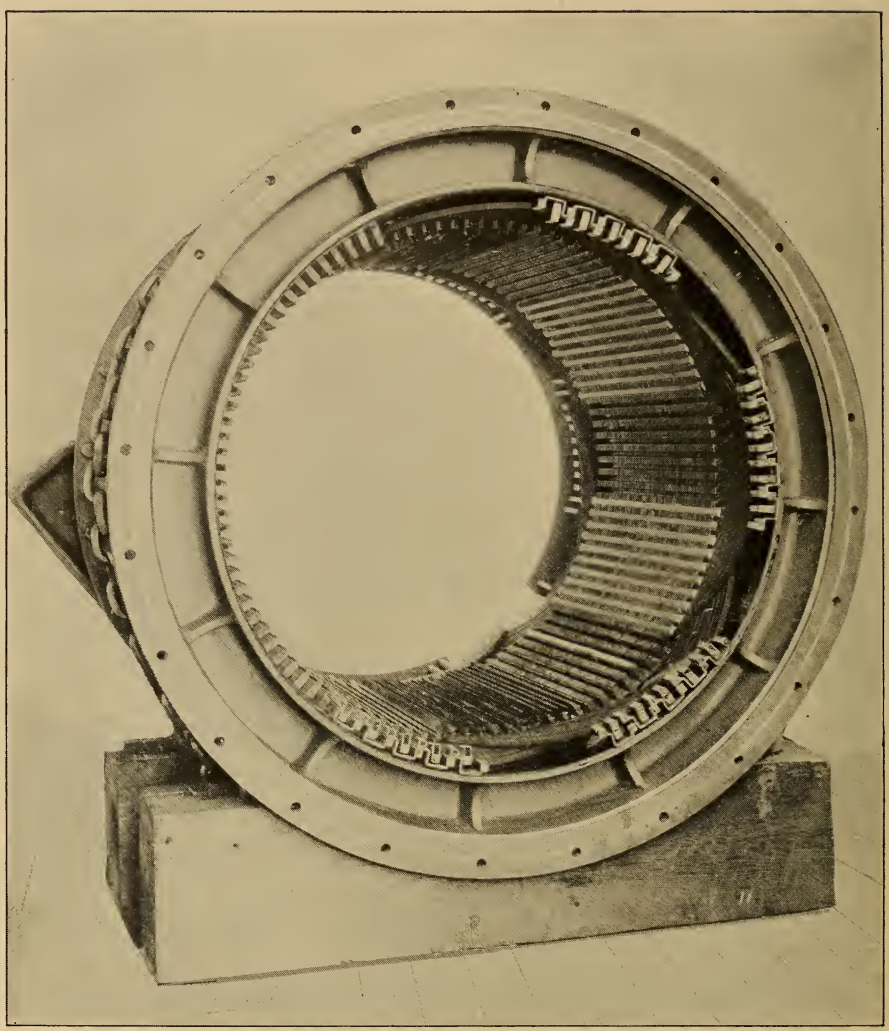
The main pipe-line is divided into divisions and sections, much like a trunk railway system, and has, similarly, its division superintendents and engineers, section foremen, line gangs and line walkers, telegraph stations and daily reports. The system works smoothly and quietly, and as the pipes are buried under ground from one to two feet, and run through a sparsely settled country, the general public sees or hears but little of the system.

A trunk line runs from the Ohio fields to Chicago, another line has been projected from these fields to St. Louis, and two other lines run from West Virginia and Pennsylvania to Philadelphia and Baltimore. The object of the pipe-lines is to cheapen the handling and transportation of oil to the great consumption centres of the country, and while there is no general distribution system at the point of delivery, the line, nevertheless, can properly be considered as a transmission of power on a large scale, where the difficulties of transmission are many and great.

The natural gas pipe line is, perhaps, a more simple example of long-distance power transmission, and bears many striking points of resemblance to transmission by electricity. The Indiana gas field covers a territory in the northern part of the State, about 38 miles long and 18 miles wide. There are about 60 wells in operation, having an



AN ELECTRIC DIAMOND DRILL FOR PROSPECTING WORK.

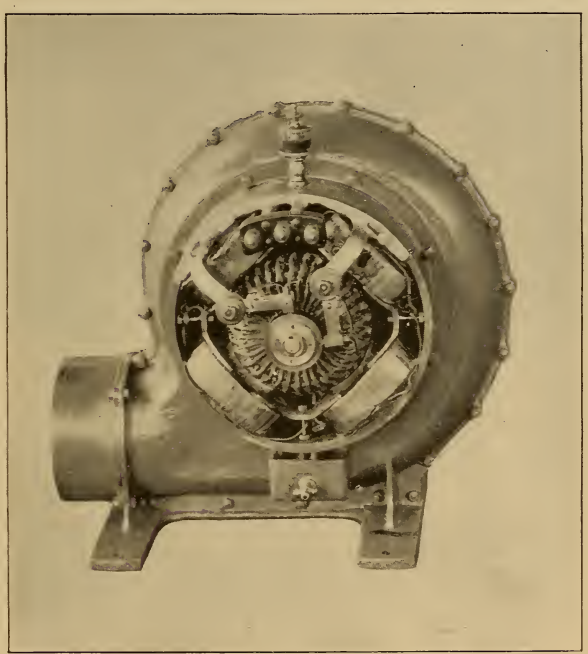


FRAME OF THE LARGE REGULATOR OF THE CARBORUNDUM CO. (SEE PAGE 339.)

average daily capacity of about 5,000,000 cubic feet each. As in the oil fields, so here, the individual wells are connected by feed pipes to a supply line, which collects the gas and carries it to the pumping-station at Greentown. There large compressors, capable of producing and sustaining a pressure of 2000 pounds per square inch, force the gas into the transmission line to Chicago. The normal pressure carried on this line is 300 pounds per square inch, which admits of a daily delivery of 10,000,000 to 12,000,000 cubic feet of gas in Chicago.

Along the line, which consists of two 8-inch wrought-iron pipes, laid 2½ feet under ground, are located what are known as "by-pass" stations, about 20 miles apart. At the "by-pass" either of the two main lines can be cut off and the gas sent through the other line. The stations are also utilized as headquarters for division superintendents, telegraph operators and repair gangs. At the Indiana State line the pressure

is automatically reduced, in a "regulating station," to 40 pounds, at which pressure the gas is carried into the city by two 10-inch wrought-iron pipes. From these pipes it is fed into an extensive system of distributing mains, throughout the city, the pressure being again reduced to less than 1 pound per square inch. From the city mains the gas is delivered to individual customers for cooking, heating and operating gas engines, and for applying heat under steam boilers, at a price much cheaper than the ordinary illuminating gas.



AN ELECTRICALLY DRIVEN BLOWER.

We have here an example of a great natural force of nature, harnessed by man, carried to a distant point, and there distributed and sold for many purposes and to many customers, at a cost below that of the same force locally produced and distributed. The analogy between the *commercial features* of this transmission and that of the Niagara power (without reference to the means of transmission) is clear and striking, even to the non-professional man. The essential *engineering features* of the natural gas transmission are :

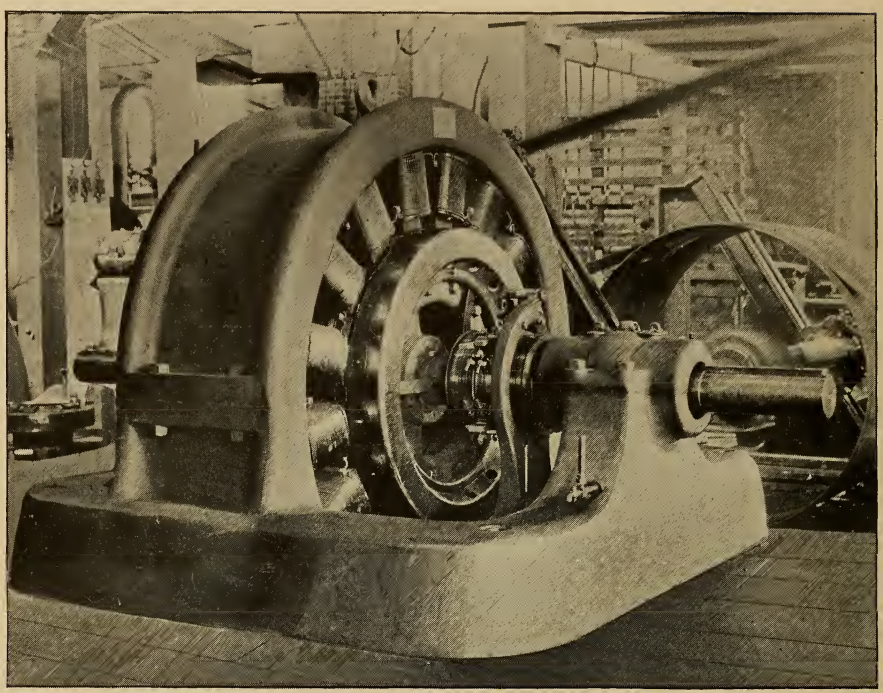
1. An initial station where the gas is collected from the wells and delivered to

2. A pumping station where the *pressure is raised* to a high point, measured by ordinary practice, in order to permit of the transmission of a large volume of the gas a great distance, with a reasonable and practicable size of transmission pipe and loss in transmission.

3. A duplicate transmission line, with stations every 20 miles, where a section of the pipe in use can be cut out for inspection or repairs, the station also serving as headquarters for those in charge of the section.

4. A line construction involving the best material (much of it specially made) and the most careful work of installation, in order to insure continuity of service and immunity from leaks, breaks or other accidents.

5. A "regulating station" at the delivery end, where the high and dan-



A 250 HORSE-POWER THREE-PHASE ALTERNATING CURRENT MOTOR.

gerous transmission pressure is reduced to one that can be safely carried through the crowded streets of a great city.

6. A distribution system in the city by which the gas, transmitted wholesale, is distributed retail to individual consumers.

7. Finally, a complete and thorough organization for the care and preservation of the plant, including, especially, a continuous and minute inspection of the transmission line, with facilities at every "by-pass" station for instant repair; in short, every facility for the maintenance of the plant in a high state of efficiency and repair.

As will be seen, the analogy between these salient engineering features and those which will distinguish the Niagara transmission is quite as marked as is the commercial analogy already noticed.

Returning now to the engineering problems of the Niagara transmission, the conductors can be carried either overhead, on a pole line of iron or wood, or a combination of iron and wood, or underground, through a subway, where cables are laid or hung in the subway, with a passageway for inspection, or in individual underground pipes or tubes. Where the conductors pass through a city, one or the other of the underground methods will, undoubtedly, be required, but for the main transmission line, across country, it is quite possible to construct an overhead line so substantial as to reduce to a small and unimportant factor the danger to the line from storms of wind, rain, snow or sleet, or from lightning. We have a practical example of such a line in the modern, long-distance, telephone trunk lines, which are the finest examples of line construction anywhere in the world, and some of which are more than 1000 miles in length.

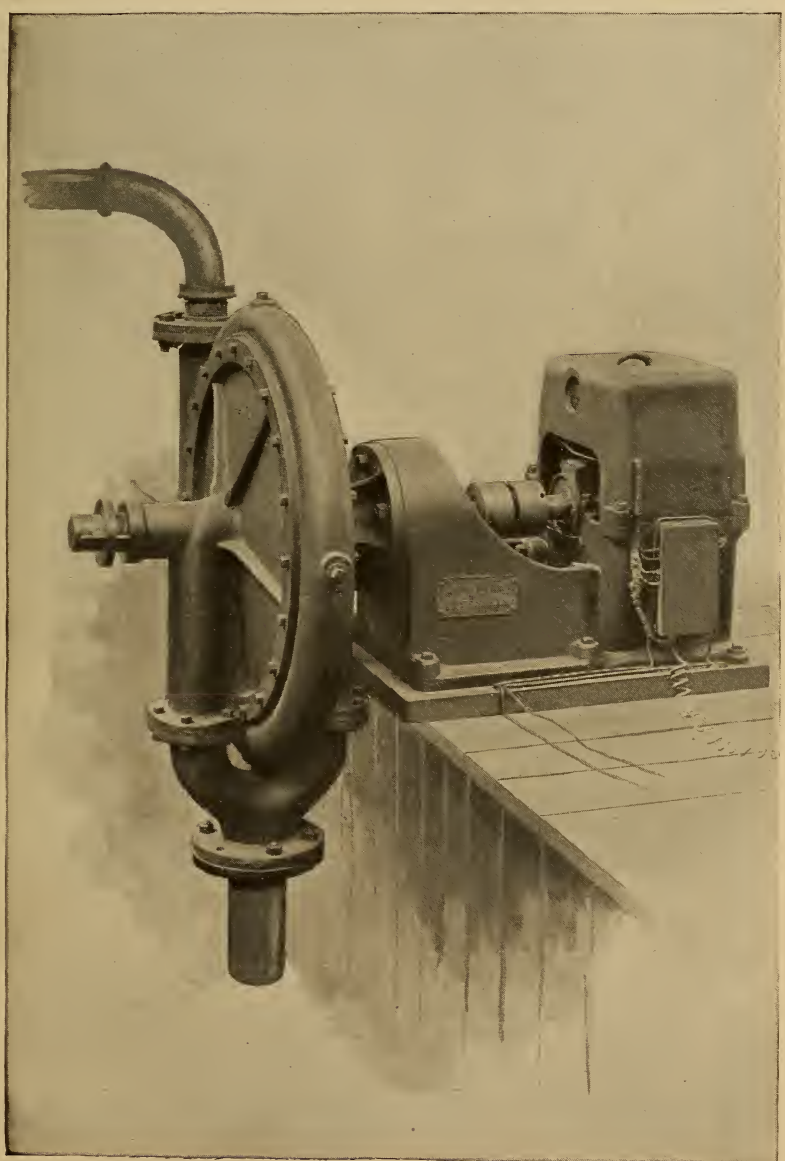
The next important question is the size and insulation of copper conductors necessary. Practical considerations limit the size of a wire for good overhead construction to one having a cross

sectional area of something less than ½ square inch ; and if a greater area be necessary, it is divided among two or more conductors. The area of conductor necessary to transmit a given amount of electric power a given distance may be expressed by the equation :

$$A \text{ (area in square inch)} = \frac{C \times N \times D}{E \times V}$$

In this C represents a numerical constant ; N the number of electrical horsepower to be delivered ; D the length of transmission line, in feet ; E the electromotive force (or pressure) at the *delivery end* of the line ; and V the loss of pressure in volts on the line, due to its resistance.

This equation applies strictly to direct currents, and while the transmis-



CENTRIFUGAL PUMP WITH DIRECT-CONNECTED MOTOR

TABLE III.

FROM	To	Distance in Miles.	H. P.	Voltage.			Remarks.
				Generator.	Line.	Motor.	
Lauffen	Frankfort, Germany	105	200	50	40,000	70	Three-phase alt. current plant for Exposition 1892. Various experiments were made on this line.
Water Power	Pachuca, Mexico	23	2,000	700	10,000	----	Three-phase Gen. Elec. Co., under construction.
Water Power	Milan, Italy	19	10,000	----	----	----	Under construction.
Tivoli	Rome, Italy	18	9,000	----	5,000	----	Ganz System, in operation three years.
Water Power	Guadalajara, Mexico	18	350	1,040	11,000	1,000	Three-phase G. E. Co., operated three years at 5,000 v. on line, last three months at 11,000 volts.
River Gorzente	Genoa, Italy	18	1,000	----	8,000	----	Ganz System.
Water Power	Santa Rosalia, Mexico	4½ / 9½	20 / 20	2,500	2,500	----	Three-phase G. E. Co., used in mining operations
Water Power	Gringesberg, Sweden	8	400	400	5,000	----	In operation three years.
Lauffen	Heilbronn, Germany	7	200	50	5,000	100	Three-phase, in operation three years.
Richelieu River	St. Hyacinthe, Quebec	5	450	2,500	2,500	----	Three-phase G. E. Co.
Bleio Schwegar	Eucheim, Germany	4	75	2,900	2,900	120	Just complete.
Padenone	Fiume, Italy	3½	100	----	3,000	----	Ganz System.
Folsam	Sacramento, Cal., U. S.	20	3,000	800	11,500	1,000	Three-phase G. E. Co. Co. alt. current, under construction.
Water Power	Telluride, Col., U. S.	15	1,000	5,000	5,000	5,000	Single-phase Westinghouse, in operation four years.
Water Power	Lowell, Mass., U. S.	9 & 14	400	365	5,000	550 D.C.	Three-phase G. E. Co., under construction. Operates St. R. R. by rotary convertors.
Oregon City	Portland, Ore., U. S.	11	10,000	6,000	6,000	133	Ditto.
Mill Creek	Redlands, Cal., U. S.	7½	300	2,500	2,500	----	Three-phase G. E. Co., in operation 1½ years.
San Antonio Canon.	San Antonio, Cal., U. S.	7	800	----	10,000	1,000	Single-phase Westinghouse.
Baltic	Taftville, Conn., U. S.	4½	400	2,500	2,500	2,500	Three-phase G. E. Co., in operation one year.
Sewells Falls	Concord, N. H. U. S.	4	400	2,200	2,200	----	Ditto.
Water Power	Walla Walla, Wash., U. S.	4	100	2,000	2,000	2,000	Single-phase G. E. Co, syn. motor.
Water Power	Canandaigua, N. Y., U. S.	3½	100	2,080	2,080	2,000	Three-phase G. E. Co., under construction.
Water Power	Pelzer, S. C., U. S.	3	1,500	3 300	3,300	3,300	Ditto.
Water Power	Silverton, Col., U. S.	3	125	2,300	2,300	2,000	Three-phase G. E. Co., running three months.
Water Power	Bel Air, Md., U. S.	3	75	2,200	2,200	2,000	Ditto.
Water Power	Hartford, Conn., U. S.	11	300	800	7,000	800	Three-phase G. E. Co., operates station by syn. motor.
Water Power	Columbia Cotton Mills, Columbia, S. C., U. S.	¼	1,340	600	600	550	Three-phase G. E. Co., power distributed by 18 induc. motors.
San Antonio, Cal., U. S.	Pomona, Cal., U. S.	15	150	1,000	10,000	1,000	Single-phase Westinghouse, operates lights in Pomona.
Water Power	Anderson, S. C., U. S.	7	150	5,500	5,500	1,000	Two-phase Stanley Co., operates incandescent lights and induction motors.
Water Power	Mine at Bodie, Cal., U. S.	13	150	3,500	3,500	3,300	Single-phase Westinghouse, Synchronous motor.

Total, 44,105 horse-power.

sion of alternating currents involves certain other losses and disturbances between conductors, they need not be here considered, since they can be practically neglected by a proper arrangement of the conductors in a system such as is here contemplated.

In non-technical language the equation means that the area of conductor, and, hence its weight and cost, varies directly as the horse-power delivered and distance transmitted, and inversely as the electrical pressure at the delivery end of the line and loss of pressure in the line. It follows that the higher we make the delivery, and subsequently

the initial pressure, the smaller and less costly becomes the conductors. The similarity to the laws governing a similar transmission of a liquid, or gas, is noticeable. In the latter case the limit of pressure carried is the strength of the pipe-line and joints ; with electricity the limit is the insulation resistance of the conductors. For high pressures, withstood a pressure of 90,000 volts before puncture. In such a test, however, actual conditions of weather and atmosphere cannot be fully reproduced, and a safety factor of two is not too large to allow. These insulators are sometimes made in two parts, separated by oil. It is very difficult, however, to keep the oil perfectly clean, and the

SPECIAL PORCELAIN "DOUBLE-PETTICOATED" INSULATOR FOR HIGH-TENSION TRANSMISSION LINES.

10,000 volts or more, on an aerial line, insulation material on the outside of a wire cannot be depended upon, for, apart from the fact that it has not a sufficiently high inherent resistance to penetration, the weather soon deteriorates the insulation material, thus lowering its resistance to such a point as to render the insulation practically useless.

The safest and best plan is to use bare conductors, depending upon the supports at the poles for proper insulation. These supports are heavy, "double-petticoated" porcelain insulators, as shown on this page, mounted on the wooden cross-arms of the pole, like the ordinary glass insulators of a telegraph line. Such insulators have successfully best practice to-day is to use *air* separation, which, under conditions of service, is probably more reliable than a separation by oil.

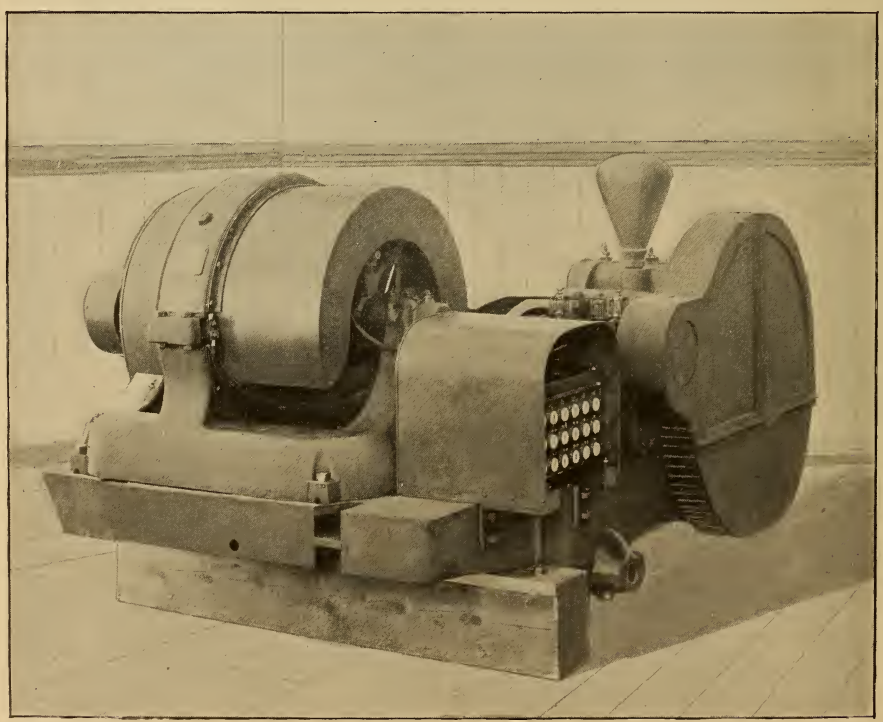
The following list of the principal transmission plants installed or in process of installation elsewhere is interesting as showing what has already been done up to date :

The plant which at once attracts attention in Table III. is the Lauffen-Frankfort transmission of 200 horse-power over a distance of more than 100 miles, and at a maximum line pressure of over 40,000 volts (this in 1892). While it is true that this transmission was on a small scale, comparatively, and while it was more or less experi-

mental in character, it is none the less significant and suggestive of what can probably be done to-day on a large scale with the wider experience and improved methods and apparatus of to-day. The next highest pressure is that on the Guadalajara line, where 11,000 volts are successfully employed. The conductors of the Lauffen-Frankfort line were bare copper overhead wires, attached to oil insulators on the poles, similar to those already described.

For the transmission of the first 10,000 horse-power to Buffalo from Niagara Falls, it has been practically decided to use 10,000 volts at the delivery end. Connections will be arranged at each end, so that this pressure can be increased to 20,000 volts, if desired. For points beyond Buffalo, it will, undoubtedly, be necessary to raise the delivery pressure still higher, in order to keep the cost of conductors within practicable limits, and for distances of 200 miles or more, the maximum Lauffen-Frankfort pressure of 40,000 volts must be equalled or exceeded. As the increase in the use of Niagara power, however, will necessarily be gradual, the pressure used, and hence the limiting distance of transmission, can be increased as rapidly as experience with lines already installed demonstrates that it is feasible and economical to do so.

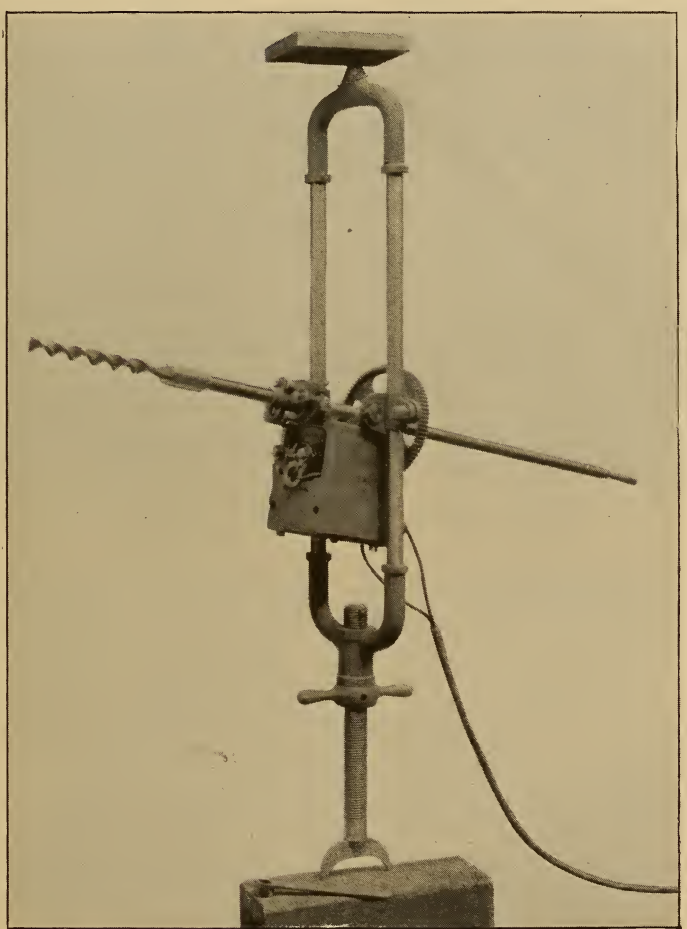
Having determined the delivery voltage to be used, the only undetermined factor in the equation fixing the area of conductors, and hence their weight and cost, is the loss of pressure in volts on the line. Obviously we can reduce this loss indefinitely by increasing the area of conductors, but this increase can be carried too far, and the economical point is where the annual charges for interest, depreciation and repairs on the whole line (conductors, pole line and labour of construction) equals the money value of the power lost in transmission. This is known as Kelvin's



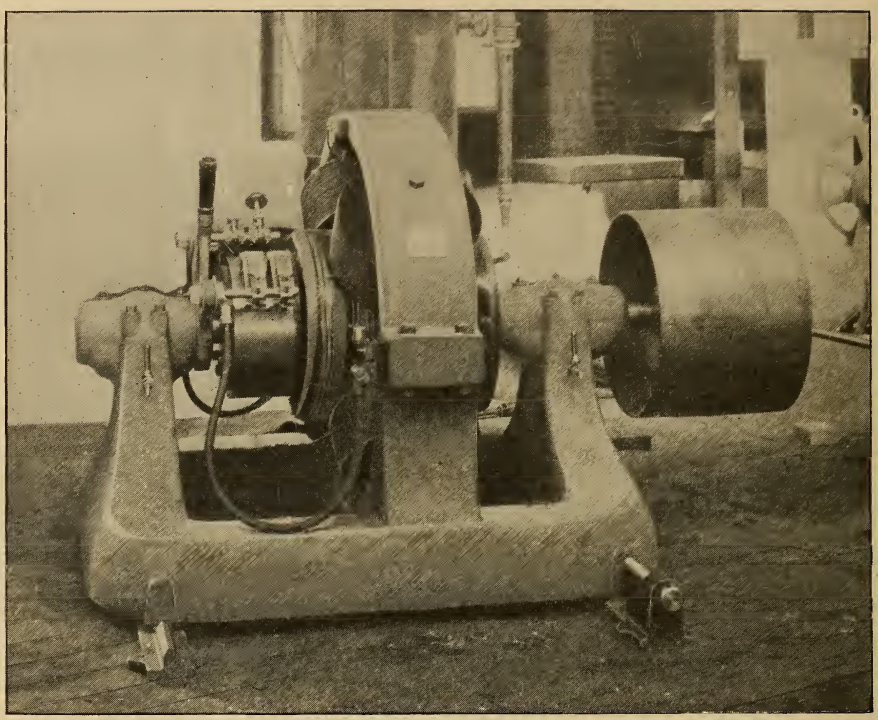
A DIRECT CURRENT ELECTRIC MOTOR, GEARED TO A PUMP.

law, and applies strictly where the total line cost increases directly as the increase in area and weight of conductors. This is not usually the case in practice, since the pole line is built with a capacity for additional wires, and the cost of conductors is therefore usually so proportioned that the interest on any additional expenditure for copper will not be offset by the money value of the power saved.

It is not practicable at the present time to build either generators or motors which will stand safely the high pressures of transmission here contemplated. It is, therefore, necessary to "step-up" the generator pressure, which may range from 1000 to 5000 volts, to the transmission pressure, and then to "step-down" the latter for delivery and distribution. This is accomplished by large static transformers, similar to those for the Pittsburgh Reduction and Carborundum plants, already described, arranged in units of from 1000 to 2000 horse-power each, in "step-up" and "step-down" stations at each end of the line. The "step-up" and "step-down" stations correspond to the pumping and regulating stations at each end of the natural gas pipe-line.



AN ELECTRIC ROTARY COAL DRILL.



A MODERN DIRECT CURRENT, SLOW SPEED ELECTRIC MOTOR.

The use of transformers makes it necessary to use the alternating current for long-distance work, and technical questions of current phase and frequency are involved in the engineering problem. A discussion of such questions, however, involves a high technical knowledge, and as their proper relations and proportions are now well understood by technical men, it is not necessary to attempt to discuss them in a paper of this kind.

It is probable that duplicate pole lines and conductors will be installed for any long distance Niagara transmission, and for distances greater than 50 miles, one or more "cut-out" stations along the line will be advisable. The conductors will be led into these stations, and connections will be so arranged that any circuit, or any wire of a circuit, can be cut out for repairs or tests, and the current switched to another circuit. The stations will also serve as headquarters for telegraph operators, division foremen, repair gangs and line-walkers.

The work of a power transmission company ends properly with the delivery of the power, at low pressure, in the "step-down" station. Its local distribution and sale are similar to those of power generated locally, and should be handled by a local company familiar with the people and with local affairs generally. Such companies have already been organized in Buffalo and Syracuse, and will, doubtless, be formed in other cities to which the Niagara power may eventually be delivered. The local engineering problems involved are such as have already been met and solved in central station practice, and need not, therefore, be discussed now.

The illustration on page 358 shows, diagrammatically, the connections of a long-distance transmission such as that to be installed from Niagara to points sixty miles or more distant. Its distinguishing engineering features, and those which will mark a departure from anything heretofore attempted, are: The size of the units (generators, motors

and transformers); the solidity and strength of line construction, and the electromotive force, or electrical pressure used on the line. The last feature is the only one that presents any unknown quantities, and it is really the one which will determine the engineering limit of the distance over which it will be possible to transmit a given amount of power from Niagara.

From experiments and tests already made on the Lauffen-Frankfort line, and elsewhere, it does not seem hazardous to predict that a maximum pressure of 50,000 volts at the delivery end of the line will be successfully adopted for long distances, if business conditions warrant the transmission. It is interesting to observe that in the transmission of either oil, gas or electricity, the limiting engineering condition is, in each case, the line pressure that can be safely carried.

One other engineering feature should be mentioned, and that is the efficiency of the apparatus and transmission line. The transformation of energy by electrical apparatus is accomplished with a very small loss, and the efficiency increases with the size of unit employed. For generators, transformers and motors of 1000 horse-power size, or larger, commercial efficiencies, that is the ratio of power delivered to power received, of from 97 to 98 per cent. at full load can be maintained; and as the load varies in a large plant, it will always be possible to keep the units that are in actual operation on full load duty, so as to realize the highest efficiency. The line efficiency

$$\left(\text{ratio } \frac{\text{Power delivered to step-down transformers}}{\text{Power received from step-up transformers.}}\right)$$

will vary with the distance and the pressure on the line. For the most economical conductor cost, the line efficiency will vary, probably, in practice, from 92 per cent. for a Buffalo delivery of, say, 10,000 horse-power, at 10,000 volts (distance 15 miles), to something less than 60 per cent. for an Albany delivery of the same amount of power, at 50,000 volts (distance about 310 miles).

The third, and last question for consideration is the cost of Niagara power, delivered at various distances, as compared with the cost of power produced

A TYPICAL ELECTRIC STREET CAR MOTOR. 25 HORSE-POWER.

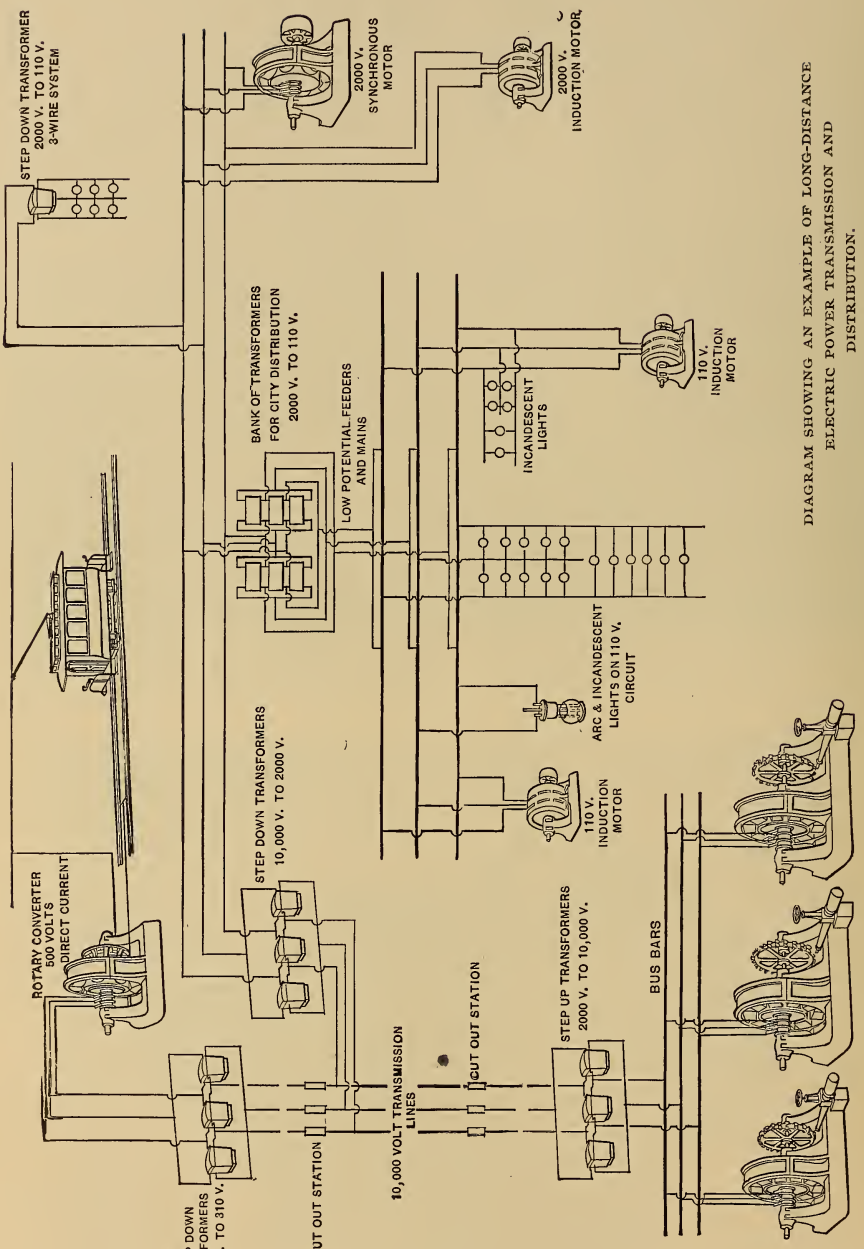

STEP DOWN TRANSFORMER 2000 V. TO 110 V. 3-WIRE SYSTEM
2000 V. SYNCHRONOUS MOTOR
2000 V. INDUCTION MOTOR
BANK OF TRANSFORMERS FOR CITY DISTRIBUTION 2000 V. TO 110 V.
LOW POTENTIAL FEEDERS AND MAINS
INCANDESCENT LIGHTS
110 V. INDUCTION MOTOR
ARC & INCANDESCENT LIGHTS ON 110 V. CIRCUIT
110 V. INDUCTION MOTOR
STEP DOWN TRANSFORMERS 10,000 V. TO 2000 V.
ROTARY CONVERTER 500 VOLTS DIRECT CURRENT
STEP DOWN TRANSFORMERS 10,000 V. TO 310 V.
CUT OUT STATION
10,000 VOLT TRANSMISSION LINES
CUT OUT STATION
STEP UP TRANSFORMERS 2000 V. TO 10,000 V.
BUS BARS
POWER STATION
2000 VOLT GENERATORS IN MULTIPLE

DIAGRAM SHOWING AN EXAMPLE OF LONG-DISTANCE ELECTRIC POWER TRANSMISSION AND DISTRIBUTION.

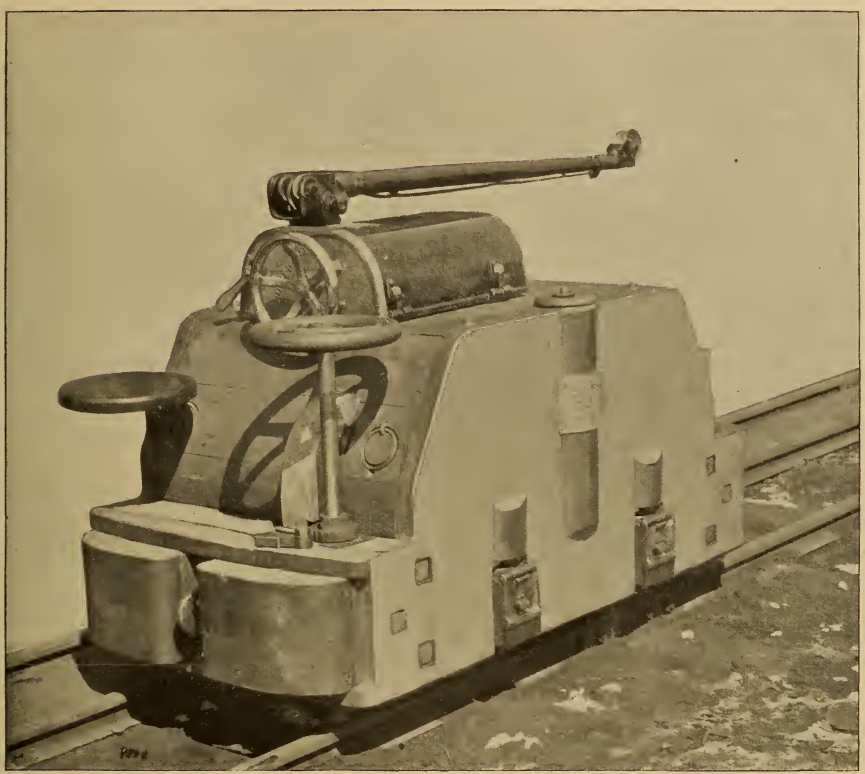
locally ; and as steam power is now generally used, either for application to mechanical work direct, or else for driving electric generators, the question is, really, the cost of Niagara electric power, delivered in bulk, versus cost of local steam power. It goes without saying that if a city, as, for example, Rochester, is fortunate enough to possess a reliable water power close at hand, and of sufficient size to provide for most of the city's requirements, Niagara power cannot hope to compete with it.

A TYPICAL ALTERNATING CURRENT INDUCTION MOTOR OF 125 HORSE-POWER.

From recent careful tests, made by disinterested experts, it appears that the cost per horse-power per annum in large and economical steam plants (1000 horse-power or more) in Buffalo, coal costing $1.50 per long ton, is about $33 for power used 11 hours per day, for 365 days a year, or $51 per horse-power for 24-hour power, for 365 days. This cost includes interest on cost of plant, insurance, taxes, operating expenses and depreciation and repairs. As the coal cost is low as compared with other cities, and as the load of the particular plant tested is unusually steady and uniform, it is probable that this cost of steam power is as low as will be found within the area of influence of Niagara electric power. It remains, therefore, to determine the approximate cost of this power, delivered at certain typical points within this area.

About a year ago, there appeared in one of the technical journals, a very interesting and able paper by Messrs. Houston & Kennelly, two well-known American electrical engineers, entitled " An Estimate of the distance to which

NINETY-FIVE-TON ELECTRIC LOCOMOTIVE BUILT FOR THE BALTIMORE AND OHIO R. R., AT BALTIMORE, MD., U. S. A., BY THE GENERAL ELECTRIC CO., NEW YORK.



AN ELECTRIC MINE LOCOMOTIVE.

Niagara water power can be economically transmitted by electricity." Assuming certain initial data, the paper estimated, in detail, the cost of delivery of certain maximum amounts of power to three points, — Buffalo, Syracuse, and Albany,—at assumed distances by wire, from Niagara Falls, of 15, 164, and 330 miles, respectively. These costs were then compared with the cost of steam power, generated locally in large quantity, under most economical conditions, and certain conclusions were drawn from the comparsion. The paper, as was to be expected and desired, created considerable comment and discussion among electrical engineers and in the technical press, and much of the data assumed and some of the conclusions drawn, were publicly criticised or questioned. The critics, however, apparently without exception, failed to appreciate the great difference in cost per horse-power and average efficiency between electric generators, motors and transformers of the size usually employed in central station practice, and those of 1000 horse-power capacity or more which will necessarily be used in the Niagara work.

They also failed to recognize the fact that, inasmuch as Niagara power will be transmitted and sold in bulk in very large quantities, it is reasonable to assume that the "load factor"

$$\left(\text{ratio } \frac{\text{Average load}}{\text{Maximum load}}\right)$$

will be considerably higher than is usual in central station electric lighting practice. The cost of local steam power assumed in the paper was also criticised as being too low, but as the figures were taken from tables carefully prepared and published by a well-known engineer, and as they agreed closely with those obtained from the test

already referred to, they were probably accurate. While some of the data and assumptions used by Houston & Kennelly were, doubtless, subject to correction in detail, they were, in the opinion of the writer, approximately correct, if taken as a whole.

The conclusion to be drawn from their figures is "that on the basis of prices and voltages assumed and detailed, the power of Niagara Falls can be transmitted to a radius of 200 miles, cheaper than it can be produced at any point within that range by steam engines of the most economical type, with coal at 12s., or about $3, per ton; that Niagara power can maintain at Albany, in New York State, a large day and night output cheaper than steam engines at Albany can develop it; but that for power taken at Albany for 10 hours per diem, the best steam engines have somewhat the advantage over Niagara, unless exceptionally favorable conditions of load could be secured for Niagara power."

Speaking of electric transmission from water powers in general, Houston & Kennelly say: "The broad conclusion to which an inquiry of this nature inevitably leads, is that while under ordinary conditions the commercial limit of electrical transmission of power from water powers of less than 500 kilowatts can hardly exceed fifty miles, the radius at which it will be profitable, with good fortune and management, to electrically transmit a water power aggregating 50,000 kilowatts, or more, is, perhaps, to-day, two hundred miles, and that it might be commercially advantageous for such a large water power to undersell large steam powers at twice this distance with no profit, in order to reduce the general expense upon delivery nearer home. The reason for this difference in the transmission radius between small and large water powers, lies obviously in the fact that electrical and hydraulic machines can be built and purchased much more economically in large sizes than in small, so that the cost of producing and of maintaining one kilowatt is very much less for large than for small water powers."

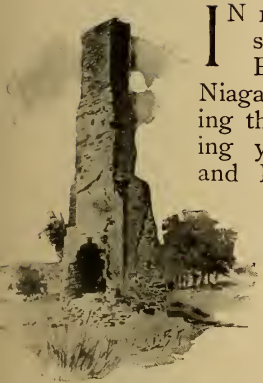
While time alone can prove the truth of these conclusions, the writer is of the opinion that, with the present cost and efficiency of steam generators, they are substantially correct. If, on the other hand, a method be discovered for transforming the heat energy of coal into electricity direct, at an efficiency comparable with that of modern electrical apparatus, the area of influence of Niagara electric power will, undoubtedly, be contracted. While such a discovery would undoubtedly be a great one, it should be stated that there is no prospect, at present, of its accomplishment. In any event, it is probable that the Niagara power company will find enough profitable business to insure a satisfactory return on the money which they have invested.

Peter A. Porter

PETER A. PORTER is prominently identified with the interests of the city of Niagara Falls. As a member of the New York State Legislature in 1886, he introduced the Niagara Tunnel Bill, under which the Niagara power is now being developed.

THE NIAGARA REGION IN HISTORY.

By Peter A. Porter.



THE OLD STONE CHIMNEY AT NIAGARA, BUILT IN 1750.

IN 1764 Sir William Johnson, commander of the English forces in the Niagara region, supplementing the treaty of the preceding year between England and France, assembled all the Indian warriors of that region, some 2000 in number, comprising chiefly the hostile Senecas, at Fort Niagara, and acquired from them, for the English Crown, together with other territory, a strip of land, four miles wide, on each bank of the Niagara river (the islands being excepted) from Lake Erie to Lake Ontario. The Senecas also ceded to him, personally, at this time, "as proof of their regard and of their knowledge of the trouble which he had had with them from time to time," all the islands in the Niagara river, and he, in turn, as compelled by the military law of that period, ceded them to his Sovereign.

It is of the territory included in the above two grants, a region now popularly known as "the Niagara frontier," that the writer proposes to treat. And a famed and famous territory it is, for it would be difficult to find anywhere else an equal area of country (36 miles long and 8 miles broad, besides the islands) around which cluster so many, so important and such varied associations as one finds there.

Through its centre flows the grand Niagara river, between whose banks the waters of four great lakes,—the watershed of almost half a continent,—find their way to the ocean; and through the centre of the deepest channel of this river runs the boundary line between the two great nations of North America. In it are located the Falls of Niagara, the ideal waterfall of the universe; in it are found the two government parks or reservations, established, respectively, by the State of New York and the province of Ontario, in order that the immediate surroundings of Niagara might be preserved, as nearly as possible, in their natural state and be forever free to all mankind. In it one meets with many and wondrous aspects of natural scenery; in it one finds geologic records, laid bare along the river's chasm by the force of the water thousands of years ago, and which hold so high a place in that science, that among its classifications the name Niagara is applied to one of the groups. In it are found botanic specimens of beauty and rarity, and it is stated that on Goat Island, embracing 80 acres, are to be found a greater number of species and flora than can be found in an equal area anywhere else. In it are to be found, also, the development of hydraulic enterprises which are regarded as stupendous even in this age of marvels; while as to places noted for historic interest, one may truly say that it is all historic ground.

Within sight of the spray of the Falls the red men, in ages long gone by, lived, held their councils, waged their inhuman warfares and offered up their human sacrifices. To this Niagara region long ago came the adventurous French traders, the forerunners of the "coureurs de bois," believed to have been the first white men who ever gazed upon the Falls, though the name of the man to whom that honour belongs, and the exact date at which he saw them will probably forever remain unknown.

Across Niagara's rapid stream went several of the early missionaries of the

THE FIRST KNOWN PICTURE OF NIAGARA FALLS.
(From Father Hennepin's "Nouvelle Decouverte," 1697.)

Catholic church as they carried the gospel to the various Indian tribes in the unknown wilderness. To this region came the French, first officially in the person of La Salle; afterwards, by the armies, seeking conquest and the control of the fur trade. At the mouth of the Niagara river the French established one of their most important posts. There they traded with, conferred with and intrigued with the Indians, making firm friends of some of the tribes and bitter enemies of others; and during the fourscore years that France held sway on the American continent, this region was a famous part of her domain in the new world.

Later on, steadily but surely driving the French before them, and finally totally depriving them of their possessions, came the English. Shortly after England became the undisputed owner of the region, the American Revolution began, and within twenty years after England had dispossessed France of this famous territory, she herself was compelled to recognize a new nation, formed by her own descendants, and to cede to it one-half, or, counting the islands, more than one-half of the lands bordering on the Niagara river. From that time on, the United States and Great Britain have held undisputed possession of all this wondrous section.

Looking back in history for the first references to the Niagara region, we find them derived from Indian tradition or hearsay, and that, almost entirely by reason of the Falls and Rapids. However, it was not their grandeur, but the fact that the Indians were compelled to carry their canoes so many miles around them that impressed them. Thus, the existence of a great fall at this point was known to the Indians all over the North American continent, we know not how far back; certainly as early as the arrival of Columbus at San Salvador.

In 1535 Jacques Cartier made his second voyage to the St. Lawrence, and the Indians living along that river narrated to him what they had heard of the upper part of that stream, and of

the lakes beyond, mentioning, in connection therewith, a cataract and a portage. Lescarbot, in his "History of New France," published in 1609, tells of this in his story of Cartier's voyage. This is the earliest reference (1535) to the Great Lake region and Niagara's cataract.

Champlain, in his "Des Sauvages," published in 1603, speaks of a "fall," which, clearly, is Niagara, and on the map, in his "Voyages," published in 1613, he locates a river with such approximate exactness as to be the Niagara beyond doubt, and in that river he indicates a "sault d'eau," or water-fall.

In 1615 Etienne Brulé, who was Champlain's interpreter, was in that vicinity, in the territory of the Neuter nation, and may have been the first pale-face to have seen the Falls. In 1626 the Franciscan priest Joseph de la Roche Dallion was on the Niagara river in the course of his missionary labors among the Neutrals. It is more than probable that at this date the Niagara route westward, as distinguished from the Ottawa route, was known and had been traversed by white men—the French traders or "coureurs de bois" previously mentioned. In the 1632 edition of his "Voyages," Champlain again, though inaccurately, locates on his map a river which cannot be any other than the Niagara, and quite accurately locates also a "waterfall, very high, at the end of Lake St Louis (Ontario), where many kinds of fish are stunned in the descent."

In 1640 the Jesuit fathers Brebeuf and Chaumonot undertook their mission to the Neuter nation, the existence of the famous river of this nation having been familiar to the Jesuits before this date. They crossed from the westerly to the easterly shore of the Niagara river, recrossing again, near where the village of Lewiston now stands, when their mission proved unsuccessful. In the Jesuit Relations we find references to this region. In that of 1641, published in 1642, Father L'Allement speaks of "the Neuter nation, Onguiaahra, having the same name as the river," and

FATHER HENNEPIN.
(From an Edition of 1702.)

in that of 1648, published in 1649, Father Ragueneau speaks of "Lake Erie which is formed by the waters from the Mer Douce (Lake Huron), and which discharges itself into a third lake, called Ontario, over a cataract of fearful height."

Sanson in his map of Canada, 1657, correctly locates the lakes and this region, and calls the Falls "Ongiara

Sault." In Davity, 1660, Le Sieur Gendron refers to the Falls in the exact words of Father Ragueneau above. In his "Historiæ Canadensis," De Creuxius very nearly correctly locates this region and the Niagara river, and calls the Falls "Ongiara Cataractes." In 1669 La Salle made a visit to the Senecas who dwelt in what is now known as Western New

RENÉ ROBERT CAVELIER, SIEUR DE LA SALLE.
(From an Edition of 1688.)

York. With him went Fathers Dollier de Casson and René Gallinée, traveling as far as the western end of Lake Ontario, whence La Salle returned eastward. Gallinée's journal of that journey includes the earliest known description of Niagara Falls, which is as follows:

"We found a river, one-eighth of a league broad, and extremely rapid, forming the outlet or communication from Lake Erie to Lake Ontario. The outlet is 40 leagues long and has, from 10 to 12 leagues above its embrochure into Lake Ontario, one of the finest falls of water in the world, for all the Indians of whom I have inquired about it say that the river falls at that place from a rock higher than the tallest pines,—that is, about 300 feet. In fact, we heard it from the place where we were, although from 10 to 12 leagues distant; but the fall gives such a momentum to the water that its velocity prevented our ascending the current by rowing, except with great difficulty. At a quarter of a league from the outlet where we were it grows narrower and its channel is confined between two very high, steep, rocky banks, inducing the belief that the navigation would be very difficult quite up to the cataract.

"As to the river above the falls, the current very often sucks into this gulf, from a great distance, deer and stags, elk and roebucks, that suffer themselves to be drawn from such a point in crossing the river that they are compelled to descend the falls and are overwhelmed in the frightful abyss. I will leave you to judge if that is not a fine cataract in which all the water of that large river falls from a height of 200 feet with a noise that is heard not only at the place where we were, 10 or 12 leagues distant, but also from the other side of Lake Ontario."

Neither Gallinée, Champlain, nor any of the other writers quoted heretofore, ever saw the Falls. In 1678 Father Hennepin visited the Falls and in 1683 published his first work, "Louisiana," in which he tells of the Niagara river and of the Falls themselves, calling them 500 feet high. On Coronelli's map of 1688 the word Niagara first appears in

THE CATARACT OF NIAGARA, WITH THE COUNTRY ADJACENT.
(From a Drawing taken on the spot by Lieut. Wm. Pierie, of the British Royal Artillery, 1768.)

cartography. In 1691 Father Le Clercq, in his "Establishment of the Faith in New France," uses the words "Niagara Falls." In 1697 Father Hennepin published his "New Discovery," in which he gives the well known description of Niagara Falls, commencing "betwixt the lakes Ontario and Erie there is a vast and prodigious cadence of water which falls down after a surprising and astonishing manner insomuch that the universe does not afford its parallel." Later on, in the same work, he describes them again, giving their height as 600 feet. He also gives in that work the first known picture of Niagara Falls, reproduced on page 366. Hennepin's two works as above, and a third, entitled "Nouveau Voyage," were translated into almost all the languages of Europe and by means of this, as well as by the work of Campanius Holm, published in 1702, who reproduces Hennepin's sketch of Niagara, and by the works of La Hontan, published in 1703, and of others later on, this region and Niagara Falls became familiar to all Europeans. It was reserved for Charlevoix and Borassow, each independently of the other, in 1721, to accurately measure the height of the Falls.

Hennepin was the first to use the modern spelling "Niagara," and he was followed by De Nonville, Coronelli and by all French writers since that time. English writers, on the other hand, did not uniformly adopt this spelling until the middle of the 18th century. The Neuter nation of Indians occupied all the territory now called "the Niagara Peninsula," by far the larger number of their villages being on the western side of the river. It was the Indian custom to give their tribal name to, or to take it from, the chief natural feature of, the country which they inhabited; hence, they were called "Onguiaahra, the same name as the river," as noted by Father Ragueneau. The Neuter nation were so called, because, living between the Hurons on the west and the Iroquois on the east,—two tribes which were sworn enemies,—they were at peace with both, and in their cabins the warriors of these two nations met without strife and in safety. The Neuters, however, were frequently at war with other tribes, and eventually even their neutrality towards the Hurons and the Iroquois disappeared and about 1643 the Senecas, the most westerly and also the most savage tribe of the Iroquois confederacy, attacked and annihilated the Neuters, their remnant being merged into the Iroquois.

There are numerous ways of spelling the Indian name of this Neuter nation, thirty-nine of them being given in the index volume of the Colonial History of the State of New York. The forms most commonly met with in early days were Jagara, Oneagerah, Onygara, Iagara, Onigara, Ochniagara, Ogniogorah, and those previously noted in this article. The word Niagara, according to Marshall, was derived by the French from Ongiara. The Senecas, when they conquered the Neuters, adopted that name as applied to the river and region, as near as the idiom of their language would allow; hence, their spelling, Nyah-ga-ah. The word, thus derived through the Iroquois and from the Neuter language, is said to mean the "thunder of the waters," though this poetic significance has been questioned by some who claim that it signifies "neck," alluding to the river being the connecting link between the two lakes. The Iroquois language had no labial sound and all their words were spoken without closing the lips. They seem to have pronounced it "Nyáh-ga-rah," and later on "Nee-áh-ga-rah," while in more modern Indian dialect, all vowels being still sounded, "Ni-ah-gáh-rah" was the ordinary pronunciation. Our modern word "Niagara" should really be pronounced Ni-a-gá-ra.

Many were the superstitions and legends which the Indians, living along the Niagara river and in the whole region, held as sacred. To the Neuter nation, naturally, the Falls of Niagara appeared in the nature of a divinity. From them they had taken their tribal name, and considered them the embodiment of religion and power. To them they offered sacrifices of many

kinds, often journeying long distances for the purpose. In the thunder of the Falls they believed they heard the voice of the Great Spirit. In the spray they believed they saw his habitation. To him they regularly and religiously contributed a portion of their crops and of the results of the chase, and exultingly offered human sacrifices and trophies on returning from such warlike expeditions as they were compelled to undertake. To him each warrior frequently made offerings of his personal adornments and weapons, and as an annual offering of good will from the tribe and a propitiation for continued neutrality, and therefore existence, they sacrificed each spring the fairest maiden of their tribe, sending her over the Falls in a white canoe, which was filled with fruits and flowers and guided solely by her own hand. The honour of being selected for this awful death was earnestly coveted by the maidens of that stoical race, and the clan to which the one selected belonged, held such choice to be a special honour to itself.

Tradition says that this annual sacrifice was abandoned, because, one year, the daughter of the great chief of the tribe was selected. Her father betrayed no emotion, but on the fateful day, as the white canoe, guided by his daughter's hand, entered the rapids, another canoe, propelled by a paddle in her father's hand, shot swiftly from the bank, followed the same channel and reached the brink and disappeared into the abyss but a moment after the one which bore his daughter. The tribe thought the loss of such a chief in such a way to be so serious a blow that the sacrifice was abandoned in order to prevent the possibility of a repetition. A more likely, but less poetic, reason for its abandonment lies in the belief that on the extermination of the Neuters, their conquerors, having no such inherent adoration for the Great Spirit of Niagara, and for many years not even occupying the lands of their victims, failed to continue the custom. The Neuter warriors also wanted to be buried beside their river, as many exhumed skeletons at various points along its banks prove; and the nearer to the Falls, the greater the honour. Goat Island is said to have been the burying ground reserved for great chiefs and brave warriors, and the body of many an Indian brave lies in the soil of that beautiful spot.

Prior to 1678 France laid claim to a vast area, now embraced by Canada and the northern portion of the United States, east of the Mississippi, including the Niagara region, by reason of early explorations and discoveries by her seamen, traders and missionaries. From that date, when La Salle began his westward journeys of exploration, for eighty years, she was a paramount force in that region, though during the last few years of that period her prowess and supremacy were waning and were swept away in 1659 by the capture of Quebec and Fort Niagara, the latter being the last of the important posts that she held in the long line of fortifications which connected the great tract, known as Louisiana, with her eastern Canadian possessions. From 1759, by occupation, and from 1763, by treaty, England owned all this territory until 1776, when the Colonists demanded recognition as a separate nation. This England conceded in 1783, and thus relinquished all ownership of that portion of the Niagara region that lies east of the river, although it was not until after the ratification of Jay's treaty, in 1796, that England relinquished Fort Niagara; nor until the treaty of Ghent, in 1816, was it absolutely conceded that most of the islands in the Niagara river belonged to the United States.

On December 6, 1678, La Salle anchored his brigantine of ten tons in the Niagara river, just above its mouth. He saw the value, from a military standpoint, of the point of land at the mouth of the river and straightway built there a trading post. Proceeding up the river to where Lewiston now stands, he built there a fort of palisades, and carrying the anchors, cordage, etc., which he had brought with him for that purpose, up the mountain side and through the forest to the mouth of Cayuga creek, five miles above the Falls on

THE WHITE MAN'S FANCY.

THE RED MAN'S FACT.

THE BUILDING OF THE GRIFFON, 1679.
(Fac-simile reproduction of the original copper-plate engraving, first published in Father Hennepin's "Nouvelle Decouverte," Amsterdam, 1704.)

the American side, where to-day is a hamlet bearing his name, he there built and launched the Griffon, the first vessel, other than Indian canoes, that ever sailed the upper lakes, and the pioneer of an inland commerce of untold value.

In 1687, the Marquis de Nonville, returning from his expedition against the Senecas, fortified La Salle's trading post at the mouth of the river, but it was abandoned during the following year. It was, however, rebuilt in stone in 1725 by consent of the Iroquois, and thereafter maintained. The site of the present village of Lewiston, named in honour of Governor Lewis of New York,—the head of navigation on the lower Niagara,—was the commencement of a portage of which the upper terminus was about a mile and a half above the Falls, the road traversed being, even now, called the "portage road." The upper end of this portage, at first merely an open landing place for boats, necessarily grew into a fortification, which was completed in 1750 and was called Fort de Portage, or, by some, Fort Little Niagara. A short distance below the site of this fort the French built their barracks. These and the fort itself were burnt in 1759 by Joncaire, who was in command, to prevent their falling into the hands of the victorious English, and he and his men retreated to a station on Chippewa creek, across the river. An old stone chimney, believed to be the first stone structure built in that part of the country, and around which were built the French barracks, stands to-day solitary and alone, the only reminder of the early commercial and military activities at this point.

It was in 1759 that the English commenced that short, memorable and decisive campaign which was forever to crush out French rule in North America. General Prideaux was in charge of the English forces thereabouts, and, carrying out that part of the plan assigned to him, collected his forces east of Fort Niagara on the shore of Lake Ontario. That fort had been strongly fortified, and this fact, coupled with its location, made its capture necessary for English success. Prideaux's demand for its surrender having been refused, he laid siege to it. He was killed during the continuance of the siege, and the command devolved on Sir William Johnson, who pushed operations vigorously

and captured the fort before French reinforcements could arrive.

These reinforcements had been sent from Venango, on Lake Erie, and, coming down the Niagara river, had reached Navy Island (Isle de Marine), then held by the French, when they heard of the fall of Fort Niagara. The certainty that the two vessels which had brought the troops and ammunition from Venango would be captured by the English, induced the French to take them, together with some small vessels which had recently been built on Navy Island, over to the northern shore of Grand Island, lying close by, into a quiet bay, where they set them on fire and totally destroyed them. As late as the middle of the present century, portions of these vessels were clearly visible under water in the arm of the river, which, from this incident, has become known as "Burnt Ship Bay."

One more historical point, the scene of the Devil's Hole massacre, is connected with the great French and English struggle. Champlain's early hostility to the Iroquois, when he sided with the Senecas against them, had made the Iroquois the firm friends of the English during all the subsequent years, and it had also endeared the French to the Senecas, even though the latter had subsequently joined the Iroquois confederacy.

After the total defeat of the French and their practical surrender of all their territory in 1759, the old hatred of the English on the part of the Senecas, abetted, no doubt, by French influences, led them to commence a bloody campaign against the English in 1763. They knew the English were, on a certain day, to send a long train of wagons, filled with supplies and ammunition, from Fort Niagara to Fort Schlosser, a station, built in 1761 by Capt. Joseph Schlosser of the English army, to replace Fort de Portage, which had been destroyed two years pre-

THE CAPTURE OF FORT GEORGE, 1813.
(From an Old Engraving.)

viously. They knew also that the military force accompanying the train was to be a small one. At a point, known as the Devil's Hole, about three miles below the Falls, and at the edge of the precipice, they ambushed this fated supply train and destroyed it, forcing both train and escort over the high bank, and killing all but three of the escort and drivers. They then cunningly ambushed the relief force, which at the sound of the firing had set out from Lewiston where the English maintained a slight encampment, and killed all but eight of these. It was a striking example of Indian warfare and of Indian shrewdness. Shortly after this, in 1763, the treaty between France and England was signed, whereby England became the absolute owner and master of the northeastern portion of the North American continent.

No serious conflict marked England's rule in her new territory, acquired by so long and fierce a struggle and at so great a cost of lives and money. But thirteen years after the above treaty was signed, the American Revolution commenced. Had Gen. Sullivan's expedition against the Senecas in 1779, been successful, as planned, he would have pursued the dusky warriors who fled to Fort Niagara, and would have attacked and probably captured that fort, then in possession of the English ; but misfortune befel him on his westward march, and the Niagara region was never the scene of actual hostilities during that war. When it closed, England had lost and relinquished to the United States all that portion of this region that lies east of the Niagara river.

The Niagara region, especially that part lying along the banks of the river, felt the full burden of the three years of border warfare between American and English forces, each with their Indian allies, known in history as the war of 1812. In the fall of 1812, about four months after the declaration of war, Gen. Van Rensselaer established his camp just east of the village of Lewiston, and collected an army for the invasion of Canada. After some delay and one unsuccessful attempt to cross the river, many of his men reached the Canadian shore and promptly and easily occupied an advantageous position on Queenston Heights. Gen. Brock hastened from Fort George, at the mouth of the river, with English reinforcements, and, in endeavoring to recapture this point of vantage, was killed at the head of his troops. Other English reinforcements having arrived, the Americans were defeated and dislodged from their position, many being forced over the edge of the bluff. Most of these and many on the brow of the mountain were taken prisoners. Meanwhile, directly across the river, on the American side, in full view of the battle, were several hundred American volunteers who basely refused to go to the aid of their companions.

The results of this first battle were most depressing to the American cause. At the foot of Queenston Heights an inscribed stone, set in place in 1860 by the Prince of Wales with appropriate ceremonies, marks the spot where Gen. Brock fell, and on the heights above a lofty column was erected to his memory in 1826, as a monument of his country's gratitude. This was blown up by a miscreant in 1840, but was replaced in 1853 by the present more beautiful shaft, within whose foundations Gen. Brock's remains lie buried.

It was in November, 1812, that Gen. Alexander Smythe, of Virginia, commanding the American army on this frontier, issued his famous bombastic circular, inviting everybody to assemble at Black Rock, near the source of the Niagara river and to invade Canada. "Come in companies, half companies, pairs or singly ; come anyhow, but come," was its substance, and about 4000 men responded. But Smythe proved incapable, and having made himself a laughing-stock in many ways, among others in challenging Gen. Porter, who had questioned his courage, to a duel (which challenge was accepted and shots were exchanged on Grand Island), the contemplated invasion was abandoned.

In May, 1813, the Americans captured Fort George and the village of Newark, both on the Canadian shore

near the mouth of the river, and held them until December of that year. So effectual was American supremacy at this time, that the English Fort Erie, at the source of the river, and Chippawa, just above the Falls, together with all barracks and store houses along the river, were abandoned, and the English evacuated the entire frontier. Fort Erie was promptly occupied by the Americans. Several minor attacks were made by small parties of English at points on the American side during 1813, one at Black Rock, where the English were badly repulsed, being the most important.

In December, 1813, the British assumed the offensive on their side of the river and soon Gen. McClure, who was in command of the American forces holding Fort George, determined to abandon it and cross to Fort Niagara. He blew up Fort George and applied the torch to the beautiful adjoining village of Newark. This was the oldest settlement in that part of Canada, was at one time the residence of her lieutenant-governor, and was further noted as the place where the first Parliament of Upper Canada was held in 1792. Its destruction was in the line of military tactics which leaves nothing to shelter an enemy when they occupy evacuated ground; but it was a severe winter, the snow was deep, and the sufferings of those whose homes were thus burnt, were excessive.

The burning of Newark raised a storm of wrath throughout Canada and England which stimulated the English forces to make great efforts for victory and retaliation. In these they were decidedly successful, for ten days later, at three o'clock in the morning, Col. Murray, of the British Army, surprised and captured Fort Niagara. Had Capt. Leonard, who was in charge of the Fort while Gen. McClure was at his headquarters in Buffalo, been vigilant, the Fort would have, probably, been successfully defended. As it was, it fell an easy prey. Lossing says: "It might have been an almost bloodless victory had not the unhallowed spirit of revenge demanded victims." As it was, many of the garrison, including invalids, were bayonetted after all resistance had ceased. The British General Riall, with a force of regulars and Indians was waiting at Queenston for the agreed signal of success, and when the cannon's roar announced the victory, he hurried them across the river to the village of Lewiston, which was sacked and destroyed in spite of such opposition as the few Americans in Fort Gray on Lewiston Heights could make.

After a temporary check on Lewiston Heights the British pushed on to Manchester (that name having been given to it in anticipation of its ultimately becoming the great manufacturing village of America) as the settlement at the Falls was then called. That place, the settlement at Schlosser, two miles above, and the country for some miles back shared the fate of Lewiston; the same was meted out to Youngstown, near Fort Niagara. The destruction of the bridge across the creek at Tonawanda saved Buffalo from the same fate, but only for a few days. Gen. Riall crossed the river at Queenston, and a few days later appeared opposite Black Rock which adjoined Buffalo. This he promptly attacked and captured. The hastily gathered and unorganized American forces not only offered little resistance, but hundreds deserted. Buffalo was burnt, only four houses being left standing, and many persons were killed.

The opening of the campaign of 1814 found an American army at Buffalo, and on July 3, Fort Erie surrendered to the Americans. On July 5, the Americans met and, after a fierce fight, defeated the British in the memorable battle of Chippawa, on the Canadian side, two miles above the Falls. Soon afterwards, the British retreated to Queenston, followed by the Americans under Gen. Brown, who then determined to recapture Fort George; but learning that the expected fleet could not co-operate with him, he changed his plans and returned to Chippawa. Gen. Scott, reconnoitering from this place in the late afternoon of July 25, found Gen. Riall with his re-

inforced army drawn up in line of battle at Lundy's Lane. Gen. Scott, with a nominal force, but with the hope of gaining time for the advent of Gen. Brown's army, immediately gave battle. Of the details of that battle, fought mainly by the glorious light of a summer moon, and continued until after midnight, with the spray of Niagara drifting over the heads of the opposing armies and the thunder of the Falls mingling with the roar of the cannon, it is not possible to recount much. The central point on the hill was held by a British battery, and it was in response to an order to capture it that Col. Miller made his famous reply, "I'll try, Sir." He did try, and successfully, and the battery, once captured, was held by the Americans against oft-repeated and brave attacks by the British.

When at last the British army retreated, the Americans fell back to their camp at Chippawa, and before they returned the next morning, the British had once more, owing to the American General Ripley's negligence, occupied the field and dragged away the cannon which had been captured from them. The battle of Niagara Falls, Lundy's Lane, or Bridgewater as it is variously called was claimed as a victory by the British, and is still annually celebrated, on the battlefield, as such. The Americans, too, regarded it as a substantial victory, and the United States Congress voted to Generals Scott, Brown, Porter, Gaines and Ripley gold medals for their services in this and other battles of the war.

The American army now returned to Fort Erie which they strongly fortified, and where they were besieged on August 3, by the British. For ten days both armies were busy preparing for the inevitable and decisive contest. Just after midnight on August 14, the British attacked the fort, but were finally repulsed. From this time to September 17, there was frequent cannonading, but on that date a sortie from the fort was made by the Americans, and was so boldly planned and so faithfully executed, that the British were completely routed, and Buffalo and Western New York saved from invasion. Lord Napier refers to this sortie as the only instance in modern warfare, where a besieging army was totally routed by such a movement. A few more desultory engagements occurred along the Canadian bank of the river, Gen. Izard having assumed command of the American army; but the season was too far advanced for any further offensive operations on this peninsula, and Canada was abandoned. Fort Erie was mined, and on November 5, 1814, was laid in ruins. It still remains so,—a picturesque spot. Some space has been devoted to this war, although not a fraction of what its importance demands. During its continuance almost every foot of land along both banks of the Niagara river was the scene of strife, of victory and defeat, of triumphs of armies and of bravery and heroism of individuals.

The treaty of Ghent restored peace to both countries, to the delight of all, especially of the inhabitants along the frontier. The commissioners appointed under that treaty to settle the question of the boundary between the United States and Canada agreed subsequently that that line, "between Lake Erie and Lake Ontario should run through the centre of the deepest channel of the Niagara river, and through the point of the Horse Shoe Fall." Later years proved this to be a variable line as far as the point of the Fall is concerned, though this fact will never impair the validity of the boundary line. By the above decision Grand Island and Goat Island became American soil, and Navy Island fell under British rule. The frontier, especially on the American side, recovered rapidly from the effects of the war, for it was a section sought by settlers, and many who reached the Niagara river on a projected journey to lands farther west, became residents of the locality.

Prior to 1825, all heavy goods were sent westwards by Lake Ontario vessels to Lewiston; thence, were carted over the well-known "Portage road" to Schlosser, and there again reloaded into vessels which went up the Niagara

river, past Black Rock and Buffalo at the source of the river, and then out into Lake Erie. Freights from the west followed the opposite course, over the same route; and this carrying trade along the frontier, controlled almost entirely by one firm, was a source of personal wealth to its members, a means of livelihood to many a family, and a prominent factor in the speedy development of the region. On October 26, 1825, a cannon in the village of Buffalo, at the source of the Niagara river boomed forth its greeting, followed, a few seconds later, by another cannon, near Black Rock; and thus thundered cannon after cannon, down the Niagara river, to Tonawanda; thence, easterly to Albany, and south, along the Hudson river, to New York city, announcing the glad message that, at the source of the Niagara river, the waters of Lake Erie had just been let into that barely completed water-way, the Erie Canal. The completion of the canal built up Buffalo, but at the same time, checked the rapid growth of the northern portion of the region, by causing a total suspension of traffic over the old portage.

Two events, entirely dissimilar and in no way connected with warlike operations, occurred in this region in the year 1826, and each attracted the attention of the whole world. The first was the proposal of Major Mordecai M. Noah to create a second City of Jerusalem within clear view of the Falls of Niagara, by buying Grand Island, comprising some 18,000 acres, and there building up for the Hebrew race an ideal community of wealth and industry. He even went so far, in his assumed capacity of the Great High Priest of the project, as to lay the corner stone of the future city of Ararat. This he did, not even within the boundaries of his proposed city, but some miles away, on the altar of a Christian church in Buffalo, to which church, clad in sacerdotal robes, attended in procession by military and civic authorities, local societies, and a great concourse of people he was impressively escorted. The Patriarch of Jerusalem, however, refused his sanction to the project, money did not pour in to its support, and it was ultimately abandoned. The corner stone was, however, built into a small brick monument at White Haven, a point on Grand Island opposite Tonawanda, and is now in the rooms of the Buffalo Historical Society.

The other event was the reputed murder of William Morgan, of Batavia, who had threatened to disclose the secrets of the masonic fraternity in print. He was quietly seized and taken away from his home, and was traced, in the hands of his abductors, through Lewiston, to Fort Niagara. There he was confined in what is still called "Morgan's Dungeon," a windowless cell that was probably used as a powder magazine. All trace of him was lost after he entered the fort, and tradition says he was taken from his dungeon by night, placed in a boat, to be sent, as he was told, to Canada, rowed out on Lake Ontario, and forced into a watery grave. Several persons were arrested and tried for his murder, but no proof of their being directly concerned in the matter, nor, in fact, any direct proof of Morgan's death being introduced, they were discharged. Some persons, however, were sentenced to imprisonment for conspiracy in connection with the matter. Thus the episode upon which the famous, powerful and widespread anti-masonic agitation was based, occurred in, and became an integral part of Niagara's history.

In the same year, the first survey and report were made at Lewiston on a project, which, so far as any commencement of it is concerned, is now as remote as it was then. Yet, it is a project which has a national importance, on which, in at least four surveys, the United States Government has employed some of its greatest engineers, and one which has, on numerous occasions, been discussed and advocated by commercial bodies, and in the halls of the United States Congress; namely, a ship canal, of a capacity large enough to float the largest war vessels around the Falls of Niagara. From a point from two to four miles above the Falls, to the deep and quiet waters near

Lewiston, has been the route most generally approved for such a canal, of which the cost would be enormous. The resulting benefits, however, especially as the population and wealth of the United States increase, might be inestimable, especially in the event of a war with England and Canada.

The Niagara region again became the theatre of war in 1837, when the Patriots undertook to upset the Government of Canada. While the first revolt occurred at York, now Toronto, the entire Canadian bank of the Niagara river was kept in a ferment for several months. Navy Island was at one time the principal rendezvous of the Patriots, and from there, on December 17, 1837, William Lyon Mackenzie, the leader, signing himself "Chairman pro tem of the provincial (a printer's error, which should read provisional) government of the State of Upper Canada," issued his famous proclamation to the inhabitants of the Province.

Without reference to the various intrigues carried on all along the frontier by the Patriots with their American sympathizers, of whom there were, doubtless, a goodly number, the writer would mention only the crucial event of the war, the Caroline episode. It was openly charged by the Canadians that substantial aid was being rendered from the American side to the Patriots, both by private individuals in various ways, and especially by reason of the non-interference of the national and New York State authorities when informed, on credible testimony, that arms and amunition were being shipped and other aid was being furnished from American soil to the Canadian rebels. This feeling was so bitter on the part of the English that it is not surprising that they seized the first opportunity for retaliation.

A small steamer, the Caroline, had been chartered by some people in Buffalo to run between that city, Navy Island where the insurgents were encamped, and Schlosser, on the American side, where there was a landing place for boats and a hotel. They maintained that it was a private money-making venture, transporting the sight-seers to the Patriot's camp; but from the Canadian's view the real object was to convey provisions and arms to their enemies. On the night of December 29, 1837, the Caroline lay moored at Schlosser dock. The excitement of the rebellion had drawn many people to this locality, the little hotel was filled and some persons had sought a night's lodging on the boat.

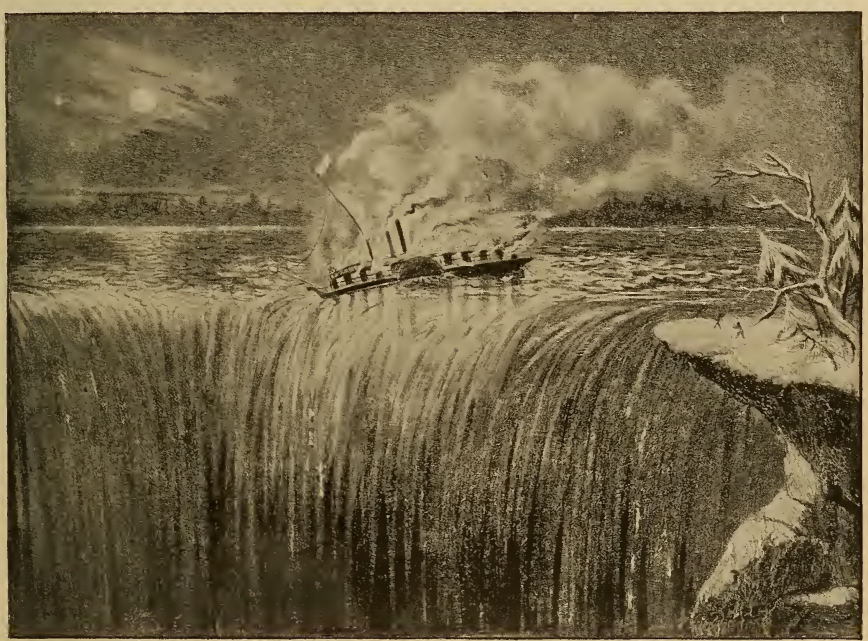
At midnight, six boats, filled with British soldiers, sent from Chippawa by Sir Allan McNab, silently approached the Caroline. The soldiers promptly boarded her, drove off all on board, both crew and lodgers, cut her adrift, set her on fire, and again taking to their boats, towed her out to the middle of the river and cast her loose. And a glorious sight, viewed merely from a scenic standpoint, it was. The clear dark sky above and the cold dark body of water beneath. Ablaze all along her decks, her shape clearly outlined by the flames, she drifted grandly and swiftly towards the Falls. Reaching the rapids, the waves extinguished most of the flames; but, still on fire, racked and broken, she pitched and tossed forward to and over the Horse Shoe Fall, into the gulf below. The whole affair, the incentive therefor, the methods employed, and the manner of the attack caused intense excitement, and once again the Niagara frontier was threatened with war, and the militia along the border were actually called into the field.

Long diplomatic correspondence followed, the British Government assuming full responsibility for the claimed breaches of international law and the acts of her officers. During the melée at the dock, one man, Amos Durfee, was killed. A British subject, Alexander McLeod, claimed to have been one of the attacking force, was soon after arrested on American soil and was tried for the murder in New York State, but was finally acquitted. War was wisely averted, but another fateful chapter had been added to Niagara's history.

With the exception of the Fenian outbreak on the Canadian side of the

river in 1866, the region has been free from war's alarms since the days of the Patriots. The Fenian outbreak was one of the results of the plan of the revolutionary Irishmen to oppose the English Government, and to compel that government to restore Ireland's rights. The Fenian hostility to Canada was solely because of the fact that the latter was an English dependency. The special time was selected, because of the actual service that many loyal Irishmen had just then seen in the United States army during the Rebellion. Of actual hostilities on this frontier there was but one occurrence during the brief agitation, fought on the Canadian side opposite Buffalo, from which city the Fenians invaded Canada. It was known as the battle of Ridgeway, the main contest having been at that point, with a subordinate engagement at a hamlet called Waterloo, close to the water's edge. The Fenians were temporarily successful, but were ultimately entirely defeated and their invading force quickly dispersed.

In 1885, the State of New York, after an agitation by prominent men for several years, purchased the land on the American side, including Goat Island and all the smaller islands adjacent to the Falls, and above and below them, for a State Reservation. In 1887, the Province of Ontario, Canada, took a similar action. The Canadian Government, many years ago, with rare foresight had reserved a strip of land, sixty-six feet wide, along the water's edge above the Falls, and along the edge of the high bank below them, from Lake Erie to Lake Ontario, as a military reserve. This is now under the control of the Canadian Park Commissioners, and, together with the additional lands acquired near the Falls, and the land around Brock's Monument, forms an ideal government reservation.



THE STEAMER CAROLINE BURNT AND FORCED OVER THE FALLS ON DECEMBER 29, 1837.
(From an Old Engraving.)

The honour of first suggesting the preservation of the scenery about the Falls has been claimed for many persons. Others, later on, suggested it officially; others still, advocated it more publicly and more persistently,

A RECENT VIEW OF NIAGARA FALLS.

but the first real suggestion, though made without any reference to details, came from two Scotchmen, Andrew Reed and James Matheson, who, in 1835, in a work describing their visit as a deputation to the American churches, first broached the idea that "Niagara does not belong to Canada or America. Such spots should be deemed the property of civilized mankind, and nothing should be allowed to weaken their efficacy on the tastes, the morals, and the enjoyment of men."

Such, in the ordinary acceptation of the word and in the briefest form, is an outline of the history of the Niagara region. Many points and facts of interest have necessarily been left untouched, but brief reference should be made to the old tramway, built from the water's edge, at the very head of navigation on the lower river, up the almost perpendicular bank, 300 feet high, close to Hennepin's "three mountains." It was used in very early days, probably before the American Revolution, for raising and lowering heavy goods between the vessels and the portage wagons, and consisted of a flat car, on broad runners, moving on wooden rails. It was raised and lowered by a windlass, and this latter was operated by Indian labour then accessible only at the Indians' own price. Braves who ordinarily would scorn to work at any manual labour, gladly toiled all day for a plug of tobacco and a pint of whiskey. The tramway was notable as being the first known adaptation of the crude principle of a railroad in the United States.

It may not be amiss to mention also, the reservation of the Tuscarora Indians, east of Lewiston, where the half-breed remnants of the last-embraced tribe of the Six Nations now reside, cultivating their fields, and educating their children under the care of the State. A tribute also is due to Canadian foresight in the building of the Welland Canal which connects Canada's frontage on the Great Lakes with her system of St. Lawrence canals to the seaboard. Mention, finally, should be made of the modern suggestion of a ship railway around the Falls, touching, at its terminals, about the same points on the upper and lower river as those held in view in the previously-suggested ship canal, and proposing, in the ascent and descent of the Lewiston mountain (which was the old shore of Lake Ontario before it receded to its present level), as remarkable a triumph of engineering skill as was shown in the enormous projected locks and one hundred-acre basin of the ship canal.

Next, glance back to the many Indian villages which, long years ago, dotted the region, the four or more of the Neuter nation, or Kahkwas, on the eastern side of the river, and a much larger number on the western side; later on, to the gradual occupation of these lands by the Senecas, almost three generations after their ancestors had annihilated the Neuters; then, to the Seneca village, built on the site of the present city of Buffalo, and then to the one built years ago on the site of the village still called Tonawanda, where, of late years, at the "long house," was annually held the council of the remnants of the Six Nations; and then at the docks in that village where once floated the Indian's canoe, and where now is seen the maze of vessels whose cargoes have, in the last two decades, built up the commercial trade of this, the second largest lumber market in America.

Turn, next, to the geological page and recall the ever fresh and still much-discussed question as to the ages that it has taken the Falls to cut their way back from Lewiston to their present location; consider, too, the question regarding the time when a great inland sea covered the whole region, of which proof is, even to-day, found in the shells which underlie the soil on Goat Island and the adjacent country. Consider, further, the query as to when and why the great flood of waters abandoned its old channel which ran westward from the whirlpool to the edge of the bluff at St. Davids, far to the west of the present outlet of the river into Lake Ontario, and how that old channel, still easily traceable, was

filled up to nearly the level of the surrounding country.

Look also at the view, given in very recent years by nature, of how her forces worked to excavate the Niagara gorge in the mass of old Table Rock, left hanging over the abyss for years and falling by its own weight in 1853. Remember the thrilling trip of the little steamer "Maid of the Mist," which, from the quiet waters of her usual, circumscribed limit below the Falls, was, in 1861, taken through the mad rapids safely into the whirlpool and, thence, through the lower rapids into Lake Ontario,—the only vessel that, during the 100 years of Queenston's existence as a port of entry, ever entered it from up-stream; and which vessel was compelled by the canny officer then in charge of the port, to take out entrance and clearance papers, although, according to these, she carried "no passengers and no freight." The trip of that little steamer proved, so far as the river below the Falls was concerned, what the courts have since decided, that the Niagara river throughout its entire length is a navigable stream.

Finally, think of Niagara as the Mecca of all travelers to the New World, think of

> "What troops of tourists have encamped upon
> the river's brink,
> What poets have shed from countless quills,
> Niagaras of ink."

Turn also to the long list of noted persons who have paid their devotions and tributes at Niagara's shrine. Potentates and princes have come, gazed on the Falls, and gone away, their visit to Niagara, perhaps like their lives, colorless and without a trace. Then, with greater satisfaction, turn to the large number of famous men and women, uncrowned, but still, by reason of their abilities, rulers of the people, who by their words, their pens, or their pencils, have given their impressions of the cataract to the world, and have, at least, earned for themselves thereby the right to be allowed a niche in Niagara's temple of fame. And numerous are the names of men and women who, in these and other ways, have connected their names with Niagara, embracing the leaders in every branch of science, knowledge and art.

There is yet another set of men whose greatest notoriety has been acquired at Niagara. Among these are Francis Abbott, "the hermit of Niagara," whose solitary life, close to the Falls themselves, and his death by drowning, have stood as a perpetual proof of the influence of the great cataract on human nature; Sam Patch, whose daring led him to make two jumps from a scaffold, 100 feet high, into the deep waters at the base of the Goat Island cliff, safely in both cases, although, not long afterwards, a similar attempt at the Genesee Falls proved to be his last; Blondin, whose marvelous nerve led him repeatedly, and under various conditions, to cross the gorge on a tight-rope; Joel Robinson, whose life was often risked thereabouts to save that of others; and Matthew Webb, whose prowess as a swimmer led him to try, unaided by artificial appliances, to swim through the whirlpool rapids, in which attempt he lost his life.

Of early Indian names on the frontier, two are specially prominent,—Red Jacket, a Seneca, the greatest of all Indian orators, who spent most of his long life near Buffalo, and died there, and who fought, with the rest of his tribal warriors, in the American army in the war of 1812; and John Brant, son of the famous Joseph Brant, a Mohawk, educated mainly at Niagara at the mouth of the river in Canada, whose first leadership in war was as an ally of the British at the battle of Queenston.

Forever and inseparately connected with the Niagara region will be the names of all of the persons here referred to, some mentioned merely as members of a class, others individually. Among the first on this roll of honour, as they were among the first to view, depict, and describe the Falls, are the names of La Salle and Hennepin,—the intrepid explorer, and the noble, though much villified, priest, for since 1678 there has been no portion of the globe to which the attention of mankind has been more, and in more ways, attracted than to this Niagara region.

Truly yours
W. Anderson

DIRECTOR GENERAL OF THE BRITISH ROYAL ORDNANCE FACTORIES.

CASSIER'S MAGAZINE.

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ELECTRIC ELEVATORS.

By Joseph Sachs.

OF the great variety of mechanical contrivances which enter into the general construction and equipment of all larger buildings there is probably none of greater importance than the modern elevator or lift. Whether for freight or passenger service its value cannot be overestimated,—a fact well demonstrated by the circumstance that the many-storied modern office or public buildings would be a practical and commercial impossibility without it. It is a matter of only about fifty years since the house elevator made its first appearance, and yet, to-day, the total number of such machines in regular use reaches far into the thousands, traveling an untold number of miles, up and down, in every day's service.

Various forms of simple manual rope and lever hoists have been known and used for ages, but the modern elevator, in which the travel is controlled from the car, appeared originally in the form of the now well-known drum hoisting machine, driven by belts from some conveniently located power shaft. Afterwards the hoisting drum was directly connected or geared to a steam engine, and eventually the hydraulic machine, with its long cylinder and multiplying sheaves, made its appearance. All of these types are still employed and have their own field of usefulness.

The most recent and probably most important outgrowth of elevator engineering is the electric elevator, which promises to supersede all of its predecessors and in America has already met with unusual success. From the various forms which have there been put on the market a number have been selected for reference here. The earliest application of the electric motor to elevator machinery consisted in operating an ordinary drum hoist by a motor belted to it in the ordinary manner. Probably one of the first elevators thus operated in the United States was at the Pemberton Mills, at Lawrence, Mass., in 1884. The writer also assisted in installing a machine of this kind at the American Institute Fair at New York in 1887. The latter machine, which was a fair example of the electrically driven belt power hoist, consisted of a Morse-Williams belt power screw hoist belted to a countershaft which, in turn, was operated by a Sprague electric motor, constantly running, after being

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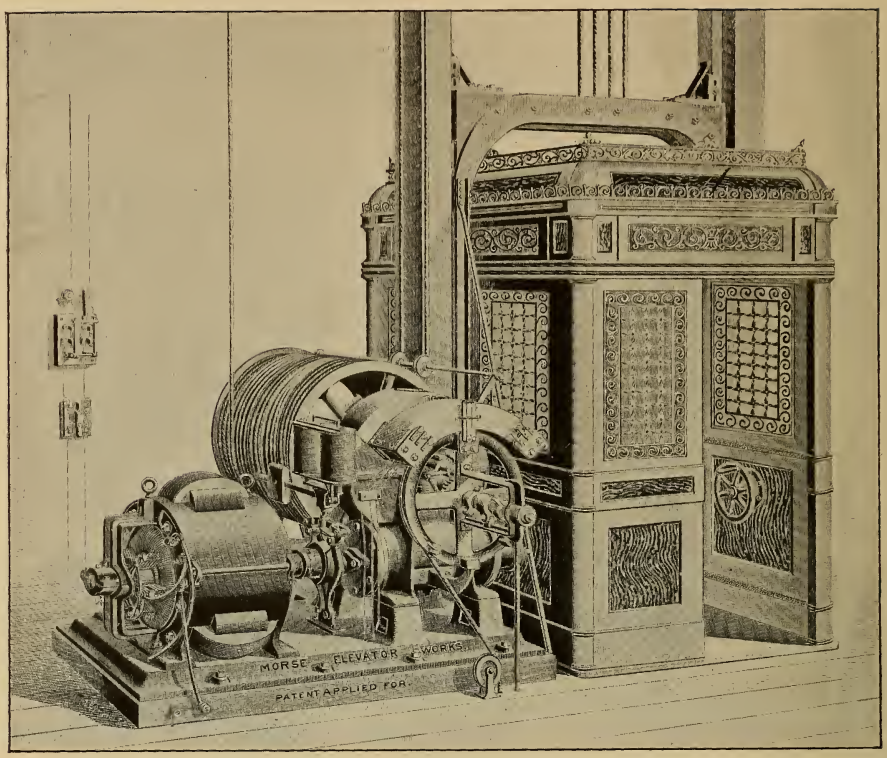


ELECTRIC ELEVATOR BUILT BY MESSRS. MORSE, WILLIAMS & CO., PHILADELPHIA, PA., U. S. A. (ELEKTRON MOTOR.)

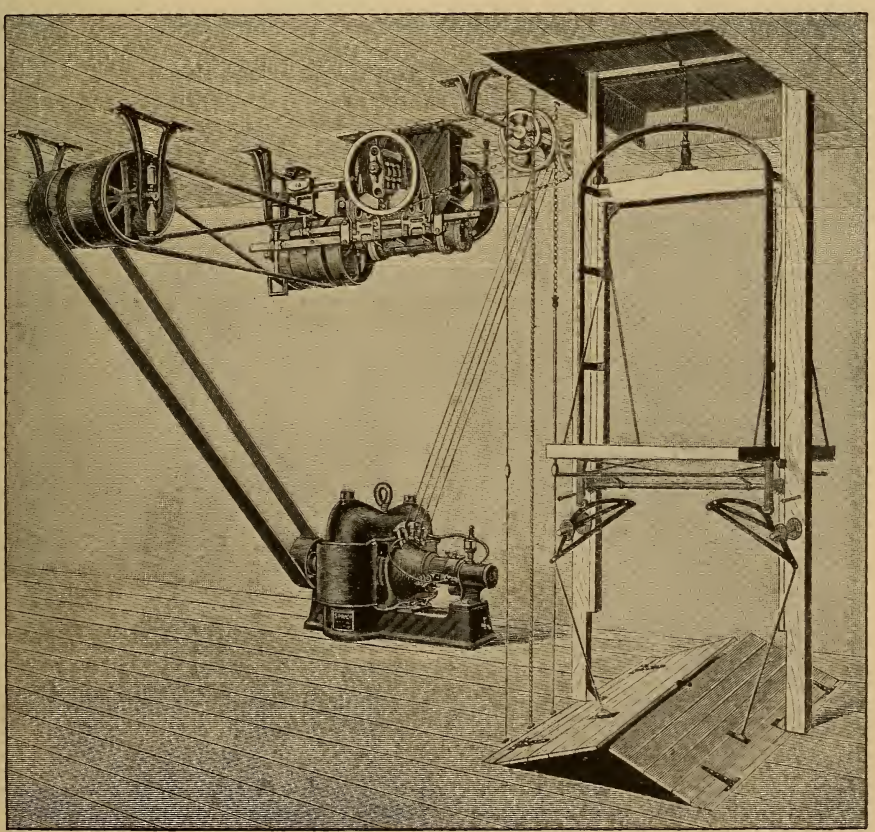
started by means of an ordinary motor starting box. The movement of the car was controlled, as in any power hoist, by means of a hand rope operating the belt shifter of the winding machine, which was equipped with the brake and safety devices common in such machines. The electric motor simply took the place of any other power such as a steam, gas or water engine and possessed the advantage of being more flexible and cleaner, and, perhaps, slightly more efficient, but otherwise retained all the disadvantages of the ordinary power hoist and, therefore, was not applicable to high-class passenger service.

The successful operation of the electric street car motor, with its direct gearing to the car axle and reversibility with fixed brushes, led to the rapid introduction of similar motors to analogous uses, and about 1888 the direct-geared electric elevator in which the motor shaft was directly connected to the hoisting machine and was started, stopped, regulated and run in either direction from the elevator car, first made its appearance. Since that time various modifications of the hoisting machinery, motor and regulating devices have been made and two distinct types of electric hoisting mechanism have been commercially developed—the winding drum machine, in which the hoisting cables, attached to the elevator car, are wound on a drum rotated by a motor in either direction, and the screw and sliding nut machine, in which the cables run over a number of multiplying sheaves attached to a crosshead which is moved longitudinally along a rotating screw driven by a motor.

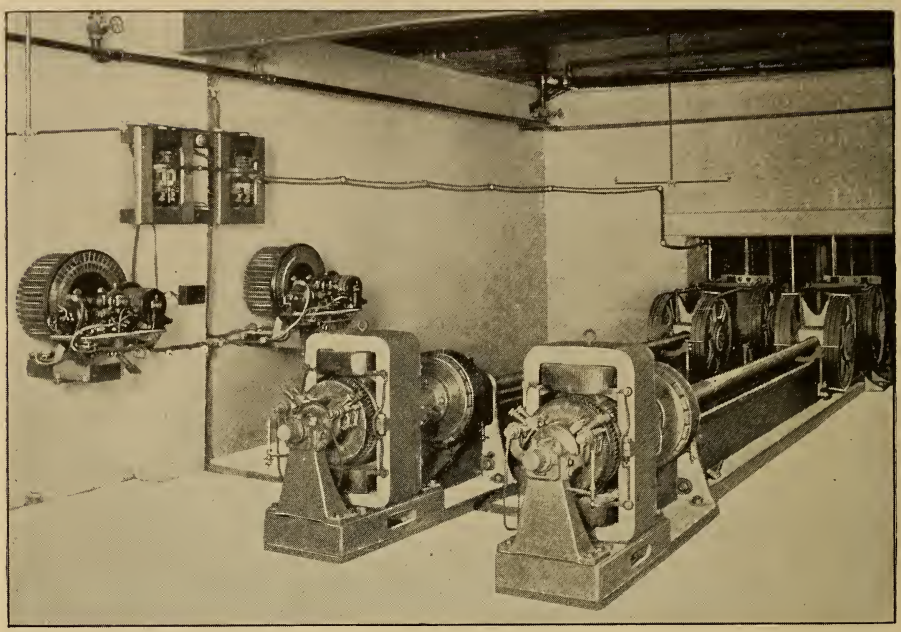
A variety of other methods have also been devised and patented in

which the electric motor is placed directly on the elevator car. In some of these the hoisting cable is dispensed with and the car raised or lowered by a screw or pinion driven by the motor and working in a vertical rack which extends along the shaft. In some others suitable gripping mechanism operates on a fixed cable passing through the car and anchored top and bottom. These, however, have no practical value as compared with the ordinary methods by which the car is raised and lowered by means of the usual hoisting cables operated by stationary apparatus.

Of the two types of elevating mechanism above mentioned, the drum winding machine is, at the present time, in most general use. Such machines generally employ a constant-potential, slow speed, direct-current electric motor capable of giving a heavy starting pull and running in either direction with fixed brushes. The armature shaft is directly geared, by means of worm gearing, to a grooved winding drum, generally from 30–50 inches in diameter. The drum is rotated in either direction, either hoisting or lowering the car, the motor being controlled by suitable switches, rheostats, brakes and other devices generally located adjacent to, or on the same bed plate with, the winding machines. The controlling mechanism is operated from the car either mechanically, by means of the ordinary hand rope or any of the lever or wheel devices in use on hydraulic elevators which are connected to and actuate a switch and controlling rheostat instead of a valve on a hydraulic cylinder, or it



A MORSE-WILLIAMS BELT-POWER ELEVATOR, OPERATED BY A SPRAGUE ELECTRIC MOTOR.



SPRAGUE ELECTRIC ELEVATORS AT JOHNS HOPKINS UNIVERSITY, BALTIMORE, MD., U. S. A.

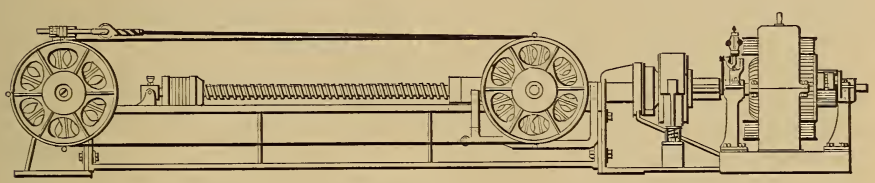
may be operated electrically by contact buttons placed in the car, connected to and controling a small pilot motor or magnet, the latter operating the controller in the desired manner. It is also possible to place the regulating devices directly on the car, but the large number of heavy cables necessary to connect them to the line and motor make such methods more or less impractical.

The braking mechanism, which is a most important element in stopping and holding the car, consists in most cases of a flat strap or band brake on the motor shaft operated mechanically by means of the hand rope, or electrically by means of a strong electro-magnet in circuit with the elevator motor. This automatically applies or releases the brake as the current is turned off or on. Various automatic safety devices are arranged to shut off the current and apply the brake when the car reaches either limit of its travel or in case the cable slackens. The gearing connecting the motor and drum always runs in oil, and while single and double drums and gears are used, the general mechanical features of nearly all drum winding electric elevators are very much alike.

Another feature peculiar to electric elevators, particularly drum winding machines, and which gives them a decided economical advantage, is the over-counterbalancing of the empty car. This, in most cases, is from twenty-five to fifty per cent. of the full weight to be carried, over that which is used to counterbalance the weight of the car. There is always a certain average percentage of the full load going up and down which can be counterbalanced, thereby economizing and equalizing the power necessary to operate an elevator. As is well known, when a constant-potential electric motor is started under load, a rush of current will flow through the motor until the latter attains normal speed. Resistance must, therefore, be introduced in starting, so as to keep this effect within reasonable limits.

When no counterbalance is used, the above effect would be intensified under

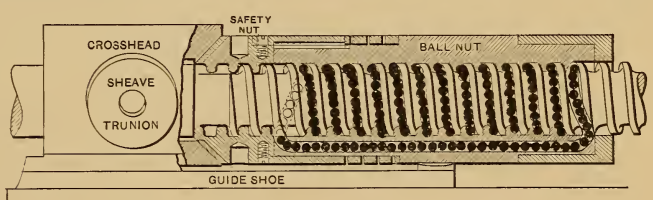
heavy loads in elevating, while in descending, practically no work would be done by the motor. This intermittent use of large quantities of current is very objectionable on electric supply systems, as it affects the other devices which may be supplied from the same mains, and also for other reasons concerning the generation and distribution of the current. It is far preferable to have a constant small load always, rather than a large load one-half of the time and none the other half.



SIDE ELEVATION OF A SPRAGUE ELECTRIC ELEVATOR.

Experience has also shown that as all the passengers going up generally also come down by the elevator, an average load can readily be arrived at. By counterbalancing to this average percentage, the motor will require much less electrical energy and the work will be more evenly distributed, as the motor will then operate in both directions. Taking a case where the full load is counterbalanced, say, thirty to forty per cent., and where this is the weight carried up and down in one trip, it will be seen that the motor has only the friction of the machinery to overcome, working either way, which is less under this than any other condition, as the strain on the gears is counterbalanced. If the weight going up be less than the counterweight, the conditions are about as above, but if the load be greater, the motor lifts only the difference between the two. Going down, if the weight on the car be less, the difference in the counterweight must be lifted, but if the car load be greater, then the motor again does extremely little work ; in fact, in this case with heavy full load and light counterweight there is some tendency to drive the motor, which effect it is, however, impractical to utilize unless the car were made to descend above its normal speed.

It will also be seen that counterbalancing to the extent of fifty per cent. of the full load above the weight of the car would require the smallest motor, as, under the maximum condition the motor would need only sufficient power to lift fifty per cent. of the capacity of the elevator. A counterbalance over or below this would require a larger motor. In the first case the motor would have to raise the heavier counterweight if the car descended empty, while in the latter the motor must lift a heavier unbalanced load in the car if fully loaded. While, however, a fifty per cent. counterbalance would require the smallest motor capacity, it would not necessarily prove the most efficient in the consumption of electrical energy if the average load amounted to less than fifty per cent. Counterbalancing is particularly applicable to passenger elevators.



DETAIL OF THE SPRAGUE NUT AND CROSSHEAD.

Considered as a whole, the drum winding electric elevator is a simple and compact machine, and one of its great points of merit is the flexibility with which it can be installed. It needs no particular preparation and can be placed at the top or bottom of the shaft

or at any intermediate point. While a great many machines of this type have been installed, they have been used at medium speeds, up to about 350 feet per minute, and on comparatively short lifts. But there is no particular reason why such machines cannot be constructed to operate at the highest required speeds and lifts. The drum would then have to be quite large, yet, where this exceeded allowable limits, it would seem possible to employ multiplying sheaves in the hoisting cable.

In the electric screw and nut machine the attempt has been made to adhere to the methods employed in the hydraulic machine, with multiplying sheaves carrying the hoisting cable, whereby the movement of the sliding nut is transmitted to the car and increased in any desired ratio. Generally considered, this type of machine comprises a long screw shaft, rotated by a direct connected slow speed, electric motor similar to those used in the previously described machines. The rotation of this shaft in either direction causes a nut and crosshead, carrying the cable sheaves, to move correspondingly forward or back on the screw shaft. The hoisting cable is anchored at one end and is carried around the movable sheaves on the crosshead and also around a fixed set of sheaves at one end of the screw, to give the necessary ratio of crosshead to car travel. In this respect these machines are similar to the hydraulic elevator design, excepting that they are generally placed horizontally.

Several electric elevators operating in this way have been devised, but the Sprague elevator is the only one which has thus far been commercially developed. In the Sprague machine the motor has its armature directly connected to the screw shaft, and current is used only in ascending. The car descends by its own weight, causing the nut to be drawn along and rotating the screw and motor armature, which, being disconnected from the line, and in circuit with a resistance, acts as a dynamo brake. Control is effected

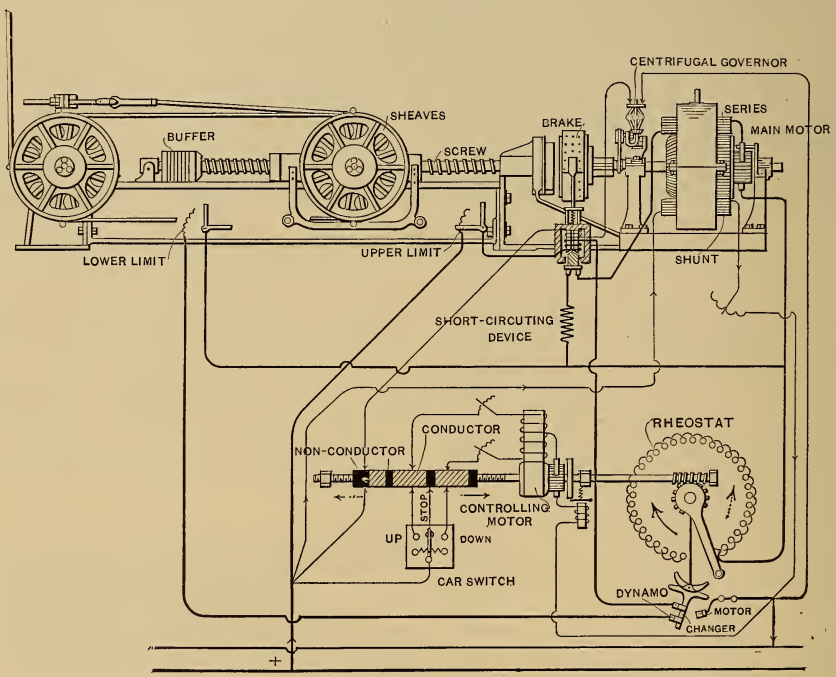
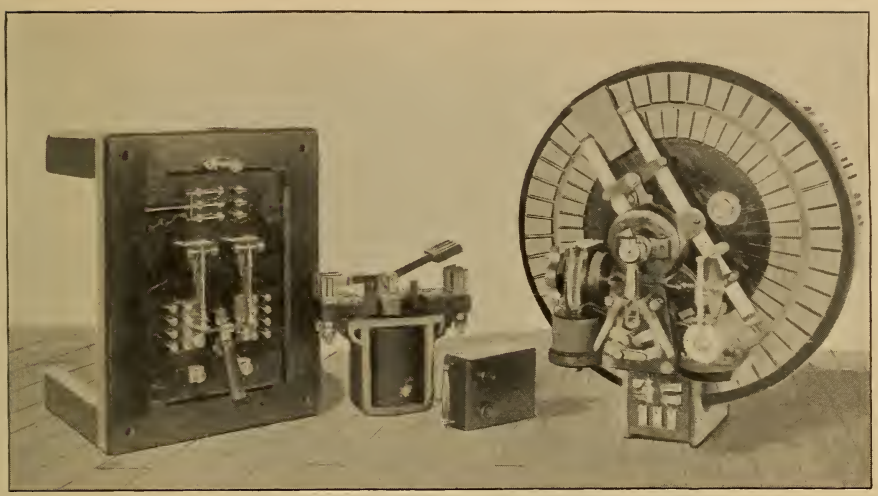


DIAGRAM OF CONNECTIONS AND GENERAL ARRANGEMENT OF THE SPRAGUE ELEVATOR SYSTEM.



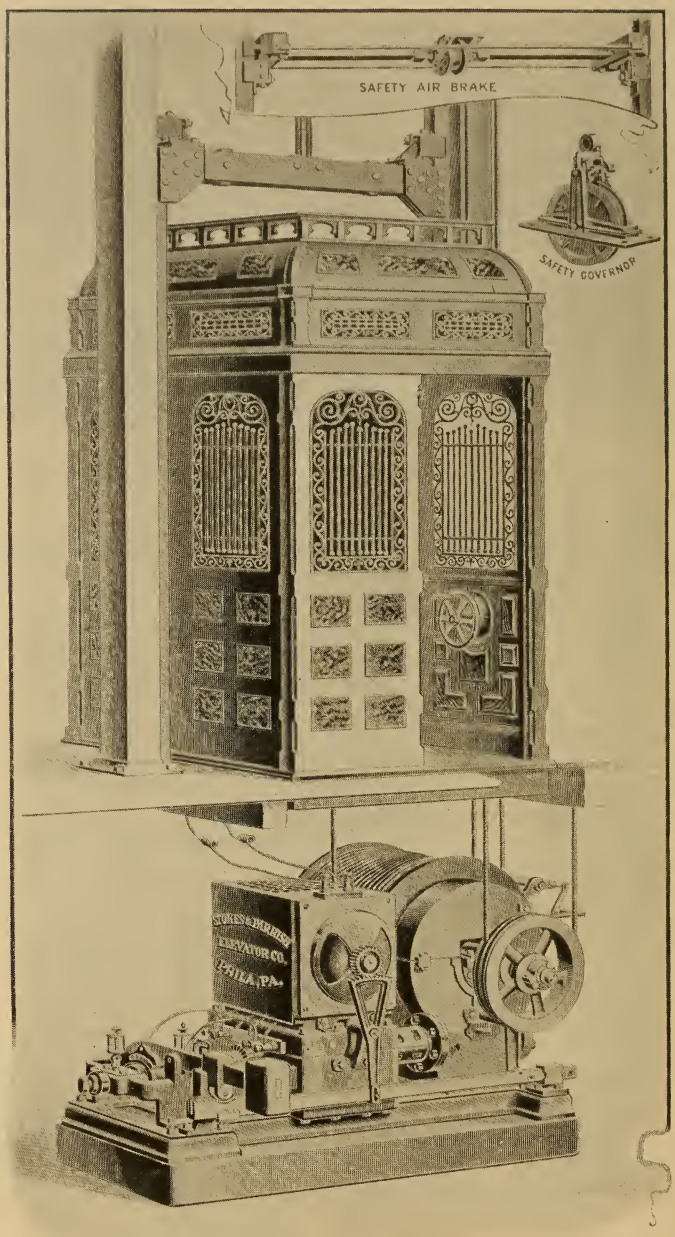
THE SPRAGUE ELEVATOR REGULATING AND CONTROLLING APPLIANCES.

electrically from the car. This method of operation does not allow counterbalancing the load, but the car is partly counterbalanced. Machines of this type can, however, be modified to permit counterbalancing and operation of the motor in both directions. This latter arrangement was adopted in an electric screw and nut elevator exhibited by the well-known American elevator builders, Messrs. Otis Bros. & Co., of London and New York, at the World's Fair at Chicago, in which the screw was operated directly by an Eickemeyer motor and regulating apparatus, as used in all the regular designs of Otis electric elevators, and the crosshead was connected to cables carrying a counterbalance and pulling in opposition to the hoisting cables. Another screw machine was exhibited at Chicago by the Standard Screw Elevator Co., of Baltimore, Md., U. S. A., in which the screw shaft was placed vertically and was driven through bevel gears by a Westinghouse motor, controlled by a rheostat and switch, operated mechanically from the car.

A more detailed description of the Sprague elevator will be of interest here. The crosshead slides on a heavy main beam, having at its lower end the fixed sheaves, and at the other the thrust bearing of the screw, the brake and the motor, which are mounted on special castings. The entire machine measures from 28–30 ft. in length.

The nut is separate from the crosshead, and there is no fastening between the two, as the friction produced by the weight of the car through the cables is greater than that between the nut and screw, thus giving a straight line movement to the nut and crosshead when the screw is revolved by the motor, and also causing a rotation of the screw by a movement of the crosshead against the nut when the car descends. The part of the nut in contact with the crosshead is not in contact with the screw, but slides on, and is keyed to, the transmission nut, there being a strong spring between the two. Between the nut and the screw are steel balls, which, after passing around about a dozen threads, circulate in a tubular passage in the nut. This ball bearing construction is a vital feature of the machine, and is used also in the thrust and sheave bearings.

The portion of the nut next to the crosshead serves as a slack cable safety. Should the strain on the cable be released for any cause, the pressure on the spring between the two portions of the nut, and therefore between the nut and crosshead, would be removed, allowing these portions of the nuts to come



ELECTRIC ELEVATOR BUILT BY THE STOKES & PARRISH ELEVATOR CO., PHILADELPHIA, PA.
(EICKEMEYER MOTOR.)

in contact with the screw with sufficient friction to cause the entire nut to turn with the shaft without any straight line movement. The nut also acts in the same way if injured, or if the end of its travel should be reached before the rotation is stopped. The screw shaft at its free end is supported by a small pivoted bearing on the main beam, the other end passing through the ball thrust bearing.

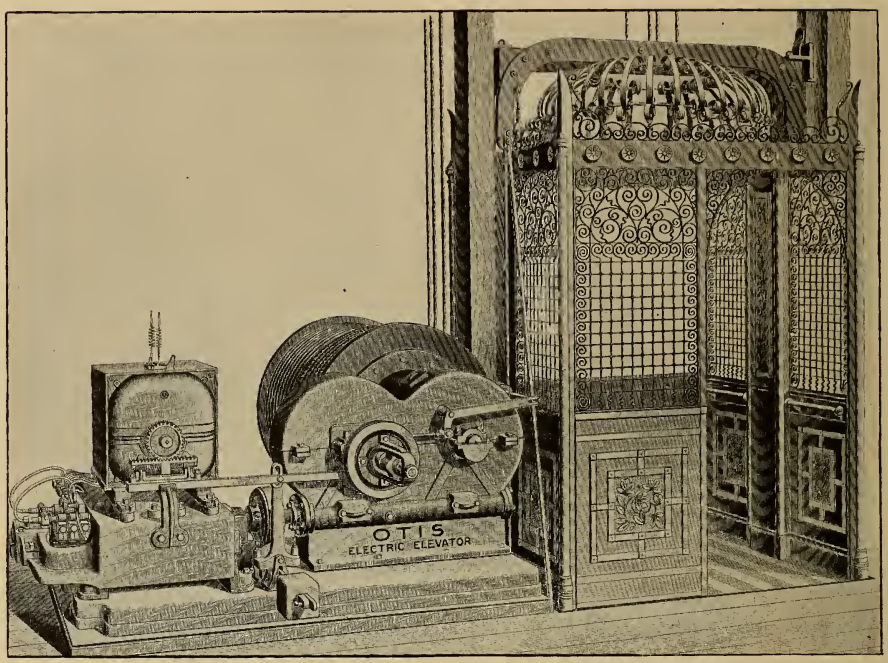
Beyond this an iron brake pulley is keyed and is connected to the motor by a flexible coupling. The brake is of the band type, anchored at one end and applied by a strong spring under compression attached to the other, which is also connected to the armature of a compound-wound electro magnet, which, working against the spring, releases the brake when energized. One winding of the brake magnet is in series with the motor, releasing the brake when current is supplied to the motor in hoisting, and the other is a shunt winding, used when descending, and controlled by a small centrifugal governor on the motor which automatically breaks the shunt winding circuit if the speed becomes too great.

The hoisting motor is of the four-pole heavily compounded type, with a slotted ironclad drum armature, with two fixed brushes, and the field and armature currents and connections are never reversed, as the motor is disconnected from the line in descending. The shunt field is always connected, and can be varied by a resistance to change the maximum speed. The regulating mechanism is separate and distinct, being connected to the motor by the necessary wires. It consists of a main motor rheostat, controlled by a small series pilot motor geared to, and operating the contact arm, and also certain contact devices which govern the pilot motor, and from which wires lead to the push-button switch on the car. A separate magnetic switch is used to cut off the line and connect the rheostat across the motor in descending, and a small switch board, also shown, contains the automatic main line switch and main circuit breaker and a throw-over switch, so that the pilot motor can also be controlled from a stationary switch.

The illustration on page 392 shows the general arrangement of the complete apparatus and connections, and explains the method of operation. As shown, the crosshead is at rest about midway on the screw. The pilot motor has two differential series field windings, one end of both being connected to the armature which operates the rheostat arm, and also a sliding contact cylinder, serving the purpose of the contacts previously spoken of. The car switch consists of a lever normally on the centre of three contacts which are connected to brushes on the cylinder. One wire from the line goes to the car switch lever, and the other to the armature of the pilot motor after passing through a small brake magnet controlling the pilot motor brake.

If the car is to be raised, the lever is connected with the up-contact, causing current to flow through one of the fields and armature of the pilot motor, energizing the brake magnet and releasing the brake, which allows the armature to rotate and turn the main rheostat arm in the direction indicated by the heavy arrow, and also pushing the changer switch onto the motor contacts. This allows the current from the main line to flow through all the main resistance, armature and series fields of the elevator motor, the series coil of the brake magnet, the upper limit switch and back to the line. While the up-button is in connection the pilot motor will continue to rotate, cutting out the main resistance and thereby gradually increasing the speed of the hoisting motor until the pilot motor is automatically stopped, and the brake applied by the up-circuit being broken at the contact cylinder which has been moved in the direction of the heavy arrow. At this point the main resistance is all out and the hoisting motor is operating at full speed.

If the car is to be stopped, the stop contact is reconnected. Current will then flow through the other field of the pilot motor, rotating its armature in the opposite direction and bringing the

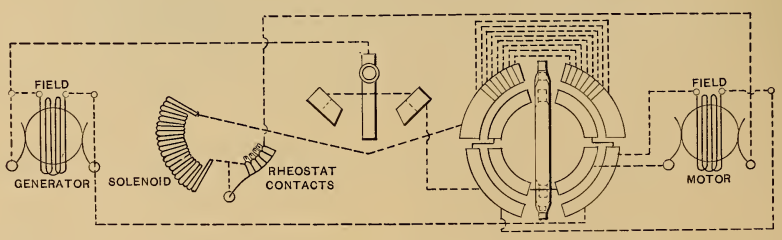


DOUBLE SCREW ELECTRIC ELEVATOR, BUILT BY MESSRS. OTIS BROS. & CO., LONDON AND NEW YORK.

rheostat arm and contact cylinders back to the original position as shown. The circuit being broken prevents the motor from continuing to rotate.

In descending, the downward contact is connected at the car switch, and current then flows through the field coil just used in stopping, the rotation of the armature moving the rheostat arm as indicated by the dotted arrow, and placing the changer switch as shown. This connects the rheostat across the motor, whose armature, being revolved by the weight of the car, acts as a dynamo working through the resistance, which, gradually being increased, allows the car to descend more rapidly. The maximum speed is attained when the down pilot circuit has been broken at the contact cylinder which has moved in the direction of the dotted arrow and has connected in the shunt coil of the main brake magnet as soon as it is started in this direction.

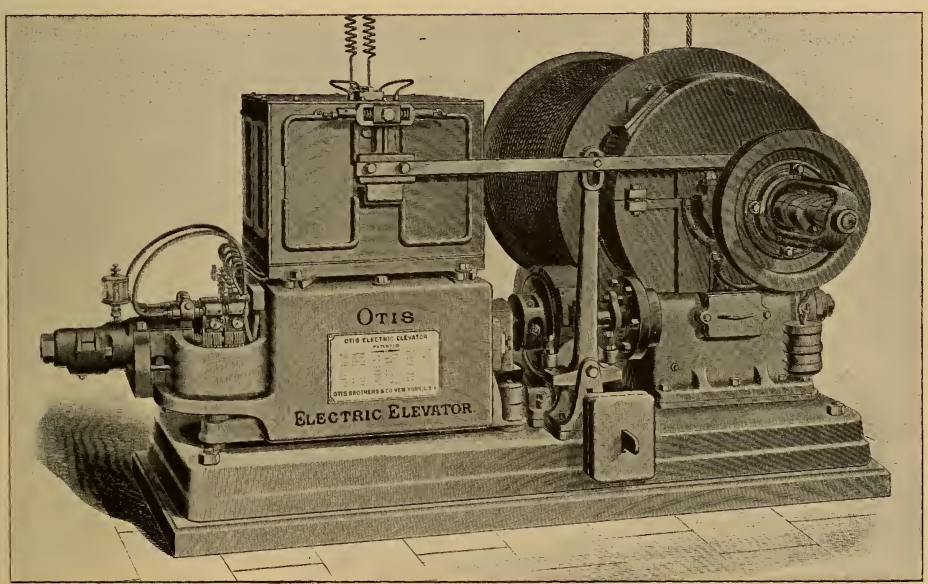
To stop the descending car, the same operation as previously is performed, connecting the other, or up, field of the pilot motor and thereby bring-



CONNECTIONS OF AN OTIS ELECTRIC ELEVATOR. (SHUNT-WOUND EICKEMEYER MOTOR.)

ing the mechanism back to its original position. The direction of car travel can also be at once reversed by connecting the up-contact or vice-versa, or the main rheostat arm may be left at any intermediate position if all the contacts are broken at the car switch before the pilot motor has automatically stopped. The latest design of car switch is arranged so that the car will automatically stop if released by the operator.

Aside from the safety devices in the



A SINGLE-GEAR OTIS ELECTRIC ELEVATOR.

nut and the usual safety appliances on the car, the machine has an upper and lower limit stop. The first, near the thrust bearing, consists of a switch operated by the crosshead when it reaches that end of its travel, and gradually opens the main circuit through a resistance which stops the motor and applies the brake. The lower limit stop operates in a similar fashion, but instead of opening the motor circuit it adds additional load in shunt to the main resistance. An additional resistance is connected across the motor whenever the brake is applied in either direction. The main controller can also be operated by an ordinary hand rope or similar device. The electric method here described can also be applied to other elevators.

It is claimed that the particular merit of this machine is its adaptation to high speeds and travel, minimum of friction, dynamic control and operation of the motor in ascending only.

One of the most extensively used drum-winding electric elevators is that built by the well-known firm of Otis Bros. & Co., of London and New York. This machine has a single grooved winding drum, carrying the hoisting and counter-weight cables. In some of these machines the drum is driven by a single worm on the motor-shaft, meshing into a single worm wheel on the drum, while in others, particularly in those used for passenger service, a double interlocking gearing is used. This consists of a right and left hand worm on the motor shaft, one operating the worm attached to the drum directly, while the other drives another separate worm wheel which meshes into the drum gear. With this arrangement no thrust bearing is neces-

sary, and the work is divided between the two worms and gears instead of being performed through only one. The pressure on the gears and the consequent wear is therefore diminished.

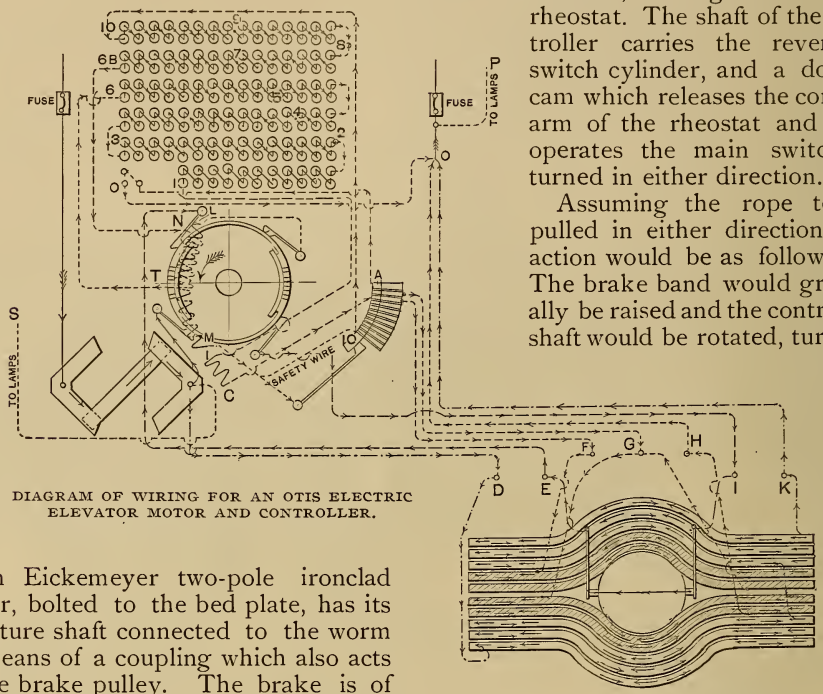
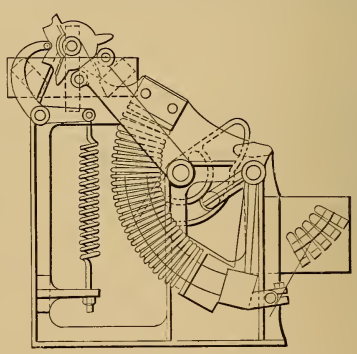


DIAGRAM OF WIRING FOR AN OTIS ELECTRIC ELEVATOR MOTOR AND CONTROLLER.

An Eickemeyer two-pole ironclad motor, bolted to the bed plate, has its armature shaft connected to the worm by means of a coupling which also acts as the brake pulley. The brake is of the band type, anchored and applied by means of a weighted lever. The motor field is highly compounded, but the series winding is cut out after the motor has attained its normal speed. A smooth core drum armature, wound on the Eickemeyer movable coil plan, is used.

Control of the motor is effected in most cases by means of an ordinary hand rope, operated directly or by a suitable lever or wheel device, the rope passing over a loose sheave on the shaft of one of the worm gears. This controller sheave is connected by a bar with the brake lever and with a shaft operating the various devices in the controller box located on top of the motor. By a movement of the controller sheave in either direction, the brake is gradually lifted and the main end reversing switch and rheostat of the controller are operated so as to start the motor. The method of operation will readily be understood from the illustrations on this page and on page 396, showing the details of the controller and the connections of the main and reversing switches, starting solenoid and rheostat. The shaft of the controller carries the reversing switch cylinder, and a double cam which releases the contact arm of the rheostat and also operates the main switch if turned in either direction.

Assuming the rope to be pulled in either direction, the action would be as follows :— The brake band would gradually be raised and the controller shaft would be rotated, turning the cam until the contact arm of the rheostat was released at the opening as

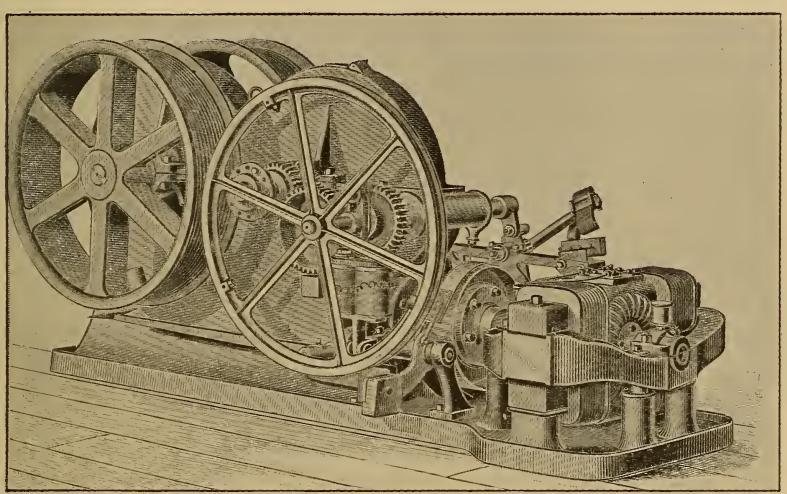


THE OTIS CONTROLLER.

shown in the illustration. Previous to this the main switch was closed and the reversing switch cylinder, also mounted on the shaft, turned so as to

make the proper connections between the four brushes thereon, two being the line and two the armature terminals. This sends the current through the armature in the direction necessary to give the desired rotation.

While in the above position, the shunt field of the motor would be connected and current would also flow through all the resistance in the controller, the series field and armature of the motor, the solenoid controlling the contact arm of the rheostat after it has been released by the cam, and also



ELECTRIC, DIRECT-ACTING DOUBLE-SCREW ELEVATOR, BUILT BY THE WHITTIER MACHINE CO., BOSTON, MASS., U. S. A. (GENERAL ELECTRIC MOTOR.)

through the main and reversing switch. This would start the motor, and as the cam reached the limit of its movement, the resistance arm, being released at the opening in the cam, would have a tendency to move over the rheostat contacts, gradually cutting out the series resistance, first part, and finally the entire series field of the motor and all the resistance, at which point the motor would operate as a shunt machine.

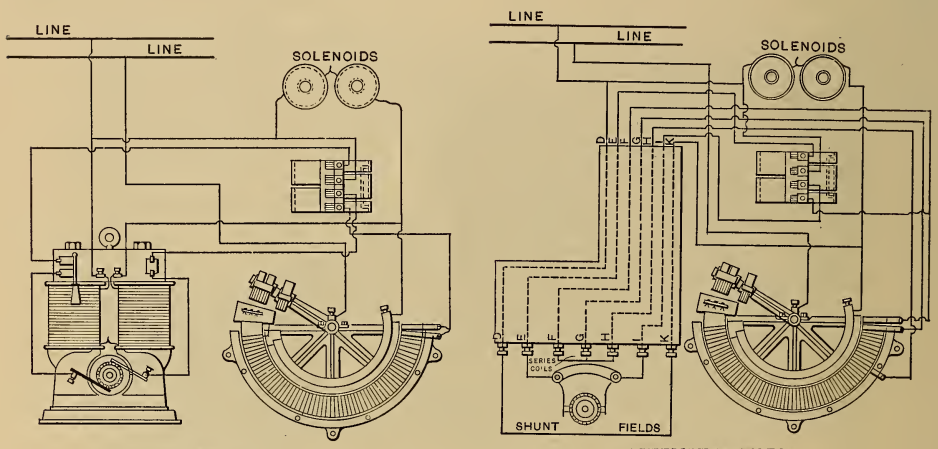
This movement of the contact arm is, however, controlled by a dash-pot connected to it and also by the solenoid which gradually releases its core, attached to the contact arm, as the current is decreased by the motor gradually attaining normal speed. Sections of the solenoid winding are also cut out as the rheostat arm moves over the contacts.

In stopping, the sheave is operated partly in the reverse direction, applying the brake and turning the controller shaft back to its former position, opening the switches and causing the cam to carry the contact arm back to its original position. By moving the sheave still further in the opposite direction, the same action as previously occurs, excepting that the reversing cylinder is turned in the opposite direction, reversing the current in the armature. Only the minimum or maximum speed can be obtained with this controller, as the resistance is all in until the arm is released at the cam opening; there it is cut out automatically. If the current becomes too heavy, caused by an overload, the solenoid will hold the arm, leaving all or part of the resistance in and preventing damage to the motor.

These elevators are supplied with limit and slack cable safety stops, both of which automatically operate the controller sheave. The limit stop consists of a sliding nut on the gear shaft which engages the loose controller sheave

when it reaches either end of its travel. For the slack cable stop, a lever, resting against the hoisting cable, is provided, and is connected with the sheave. The brake is sometimes operated by an electro-magnet in the main circuit, which releases the brake when energized, working automatically when current is off. In some Otis machines a shunt-wound motor is used, the controller and manner of operation being practically as first described.

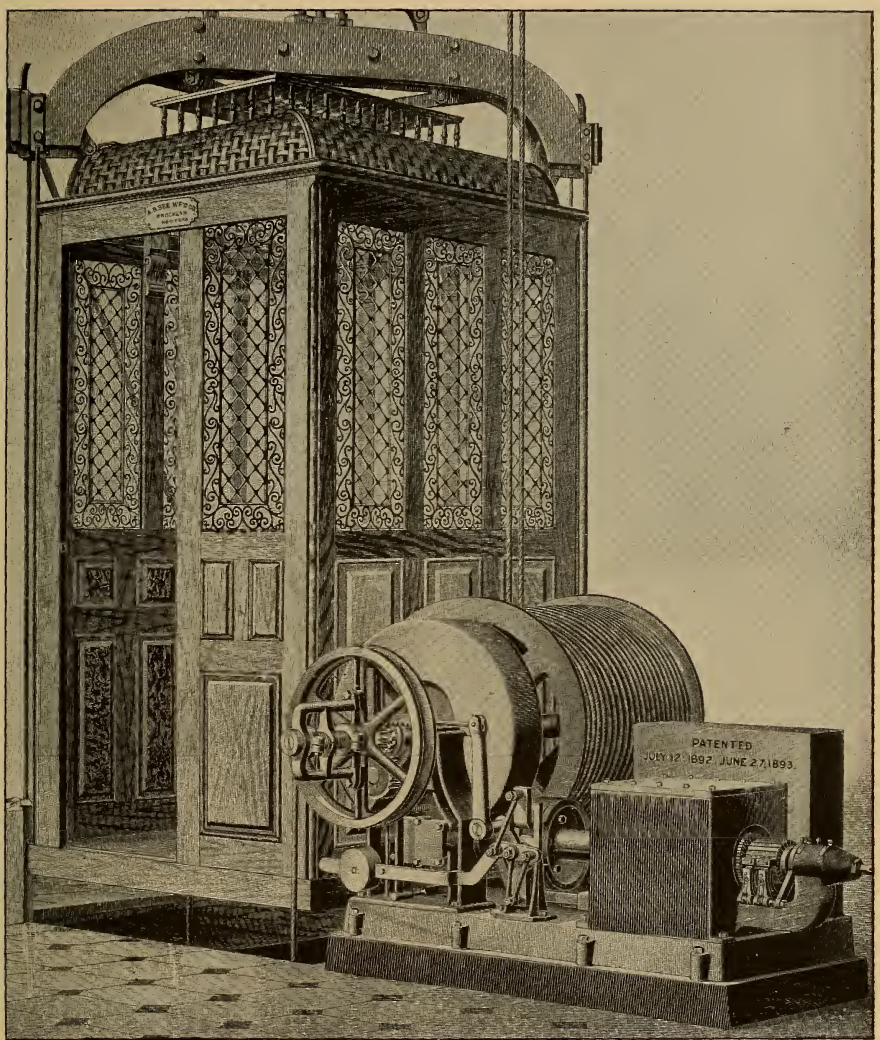
An electric system of controlling the car is also installed by the Otis company. The car is provided with a switch having up, down and stop contacts which are connected to, and operate, relays, which, in turn, operate a magnet or pilot motor controlling the main motor regulator in a manner similar to that above described. Switches, similar to the car switch, are also placed on each floor, so that the car can be operated from them, and safety switches are operated by each of the enclosure doors, preventing the operation of the car if any door is open, and also preventing operation from the floors while under control from the car switch. All the Otis electric elevators are heavily over counterbalanced in the manner previously described. The builders claim that a counterbalance of about forty or fifty per cent. is best suited and most efficient under ordinary conditions. The double gearing above described is used also in the Whittier electric elevator. This machine has a double winding drum and the gearing is placed between the two, thus equalizing the pull on both ends of the drum shaft. The armature shaft of the motor is coupled to the double worm, and the coupling acts as the brake pulley. The motor controller and brake band are operated by a rope sheave shown in the illustration on page 399. When an electro-magnet is used to release the brake, it is connected in shunt across the line and controlled from the regulator contacts.



EDISON MOTOR. EICKEMEYER MOTOR.

CONNECTIONS OF THE WHITTIER ELEVATOR

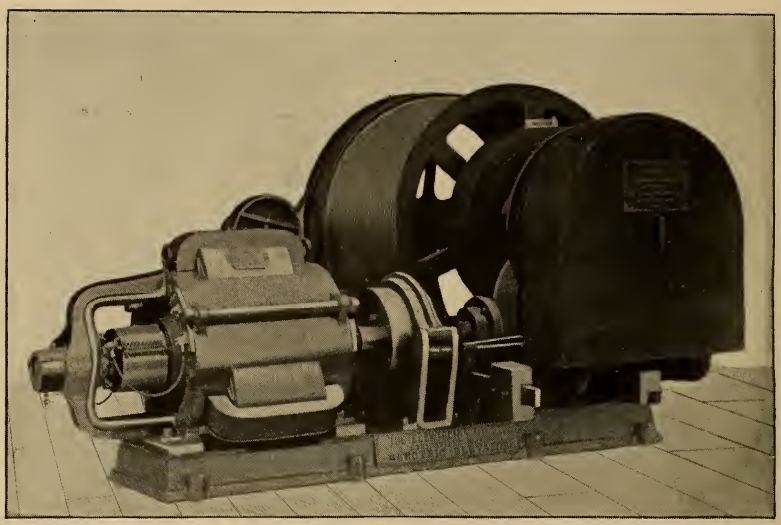
The Eickemeyer motors used are regulated by a reversing switch and rheostat, the connections being shown in the diagram on this page. The reversing switch is shown below the brake magnets. When the controller sheave is operated, the rheostat arm is turned, connecting the shunt field and brake magnet and gradually cutting out the resistance in series with the motor, part of, then all of the series field. In stopping, the arm and reversing switch are returned to their original position. The motors of the General Electric Company, of New York, which also are used with this form of elevator, are shunt wound, have a resistance in series with the armature and are operated



ELECTRIC ELEVATOR BUILT BY THE A. B. SEE MFG. CO., BROOKLYN, N. Y., U. S. A.

similarly to the above. As the rheostat is controlled entirely by the operator it can be left at any intermediate point for any desired speed. The limit stop consists of a train of gears connected with the controller and thrown into action by a traveling nut on the drum gear shaft. A lever beneath each drum, and connected to the controller, acts as the slack cable stop. Eickemeyer motors and regulating apparatus are also used on the Stokes and Parrish electric elevator.

The mechanical arrangement of the A. B. See electric elevator is shown on this page. An ironclad two-pole motor and the controller are placed side by side on the bed-plate of the machine and are operated by a loose rope sheave on the gear shaft, connected with the brake and controller arm. The motor is compounded, having a toothed drum armature, and is controlled somewhat differently than the previously described machines, as will be seen by reference to the diagram on page 402, showing



ELECTRIC ELEVATOR BUILT BY THE ELEKTRON MFG. CO., SPRINGFIELD, MASS., U. S. A.

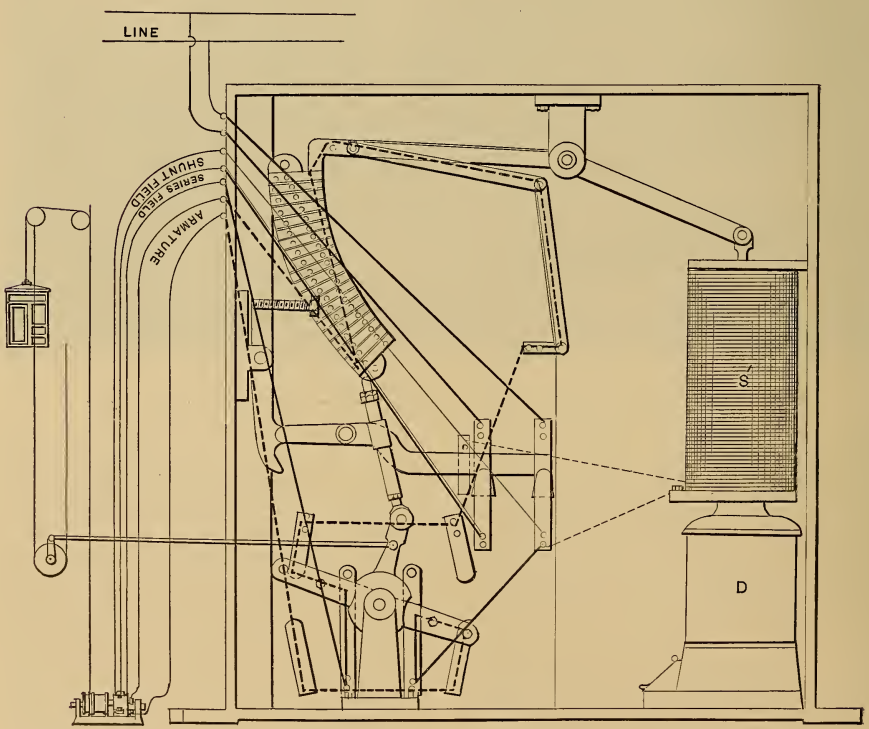


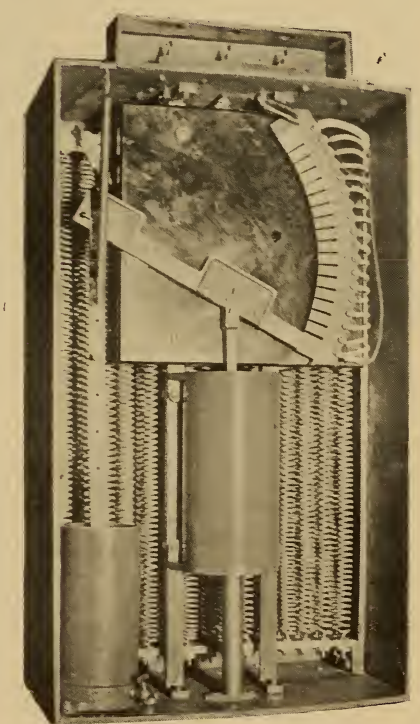
DIAGRAM OF CONNECTIONS OF AN A. B. SEE ELEVATOR, SHOWING ALSO THE INTERIOR OF THE CONTROLLER.

the connections of the motor and controller. The latter comprises a rheostat, controlled by a solenoid, and the main and reversing switches which are operated by the rope sheave, the movement of which, in either direction, closes the main switch and sets the reversing switch on either side. One end of the main switch lever rides on a spring arm, so that a snap movement is given to these switches, always ensuring proper contact. The closing of the main switch connects the solenoid, controlling the rheostat arm, across the line.

Turning the controller sheave for "up" or "down" releases the brake and operates the main and reversing switches, connecting the shunt field of the motor and the solenoid across the line, starting the elevator and allowing current to flow through the armature, series fields and all the resistance which is gradually cut out by the contact arm. The latter is operated by the core of the solenoid. The movement of the contact arm can be regulated by a dash pot, and in case of the current failing, the arm automatically returns to its original position. This arrangement permits of but one speed. The machine has the usual safety devices. The limit stop is shown with the controller sheave on the drum shaft, in the illustration. The slack cable safety stop is located beneath the drum and releases a weighted lever operating the sheave. The brake consists of two hinged shoes brought together as shown.

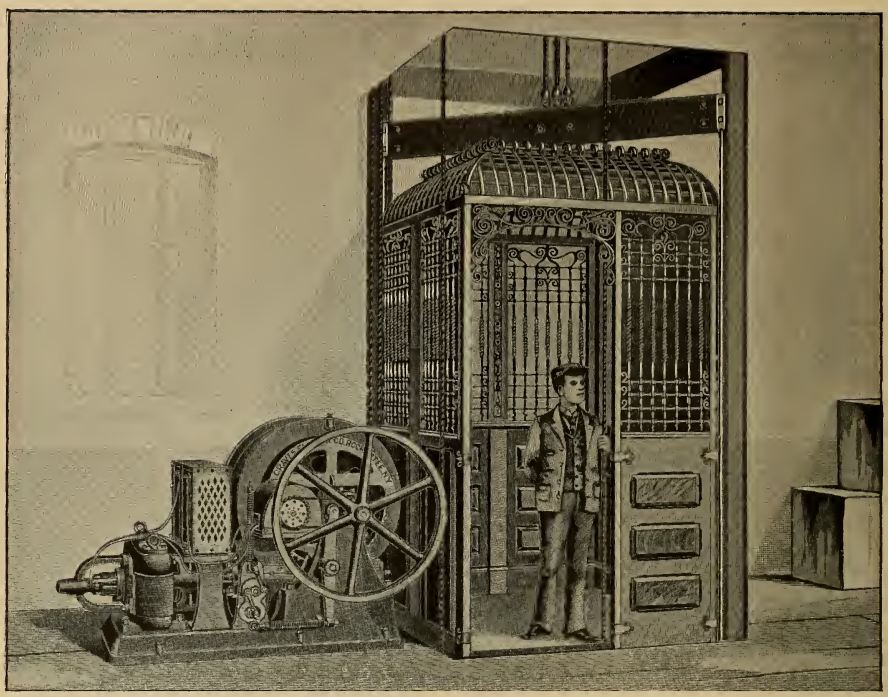
In the Elektron Company's electric elevator, a single winding drum is geared to a Perrett multipolar, shunt-wound motor, controlled by a rope sheave carrying the switches, on the drum shaft. The band brake is connected with the controller sheave and the controlling switches are also directly operated by it. The controlling solenoid and rheostat are located in a separate box which may be placed upon the wall. Moving the sheave in either direction brings the switch contacts against a number of clips which are arranged so as to reverse the direction of the motor, corresponding to the side connected. This operation sends the current through the shunt field of the motor, and also through the armature and resistance in series with it, which latter is gradually cut out by the solenoid controlling the contact arm. The gradual starting of the motor is controlled by an automatically operating solenoid, allowing only a maximum speed to be obtained.

In the latest Elektron machines the

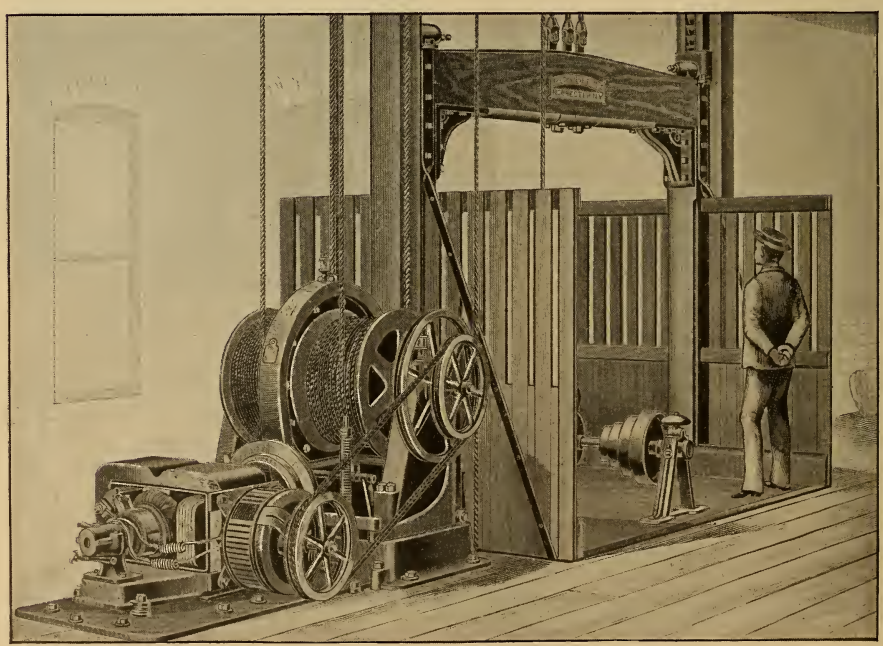


THE ELEKTRON CONTROLLER.

sheave switches are entirely enclosed. The limit safety stop consists of the usual traveling nut, engaging with the controller sheave, and the slack cable stop is operated by a lever under the drum operating a clutch which throws the sheave into connection with the rotating drum shaft. On passenger elevators a centrifugal governor operates the brake when the normal speed is exceeded. A similar arrangement of Elektron motor and switches is



ELECTRIC PASSENGER ELEVATOR BUILT BY THE GRAVES ELEVATOR CO., ROCHESTER, N. Y., U. S. A. (KEYSTONE MOTOR.)

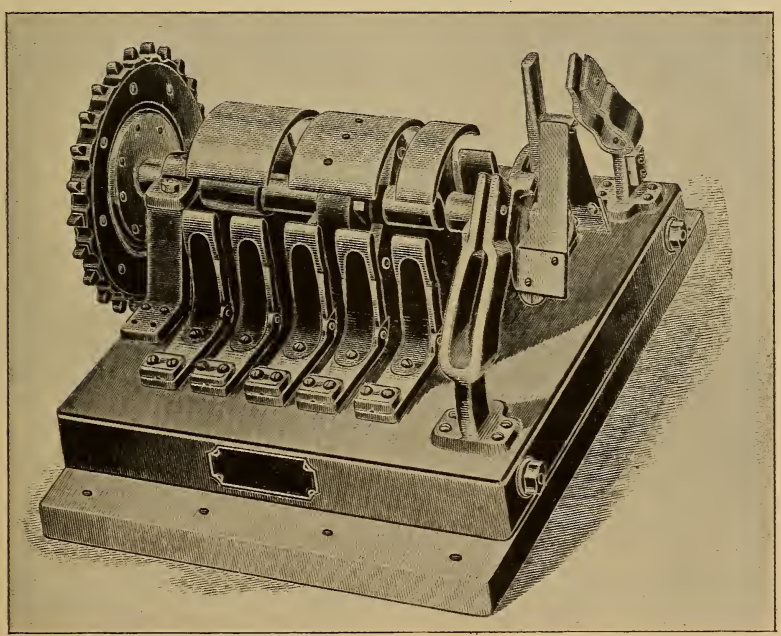


GRAVES ELECTRIC FREIGHT ELEVATOR. (GENERAL ELECTRIC MOTOR.)

used in the Morse-Williams electric elevator.

A special elevator motor and controlling apparatus, made by the Keystone Electric Company, of Erie, Pa., has been applied to a number of different drum elevators, among which is the Graves electric elevator. In this machine a single winding drum and rope sheave control are used. The motor is compounded, having a ring armature and is regulated by a rheostat and a separate reversing switch cylinder, operated by the controller sheave. has double drums at the ends of the main shaft which is operated by a double right and left hand worm gearing. The driving motor is of the iron clad multipolar type and the shoe brake is operated electro-magnetically, and is located at the outside end of the motor shaft. Between the motor and gears a speed governing and safety device is located, consisting of a closed armature on the motor shaft rotating in a magnetic field. The machine is controlled electrically.

The Moore & Wyman electric ele-

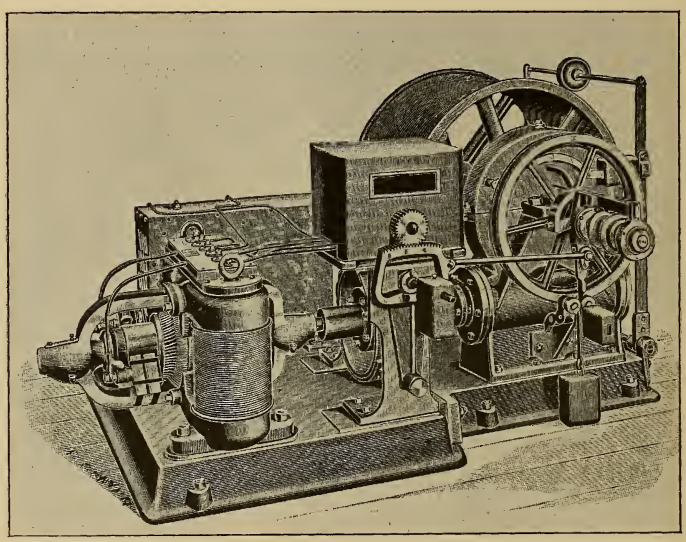


MAIN AND REVERSING SWITCHES USED WITH THE KEYSTONE ELECTRIC ELEVATOR MOTOR.

The rheostat is controlled by a magnet connected by the switch cylinder. This motor is also used in operating ordinary belt power hoists. The General Electric Company's motors are also used in the Graves elevators, being generally compound or shunt-wound and controlled by a rheostat and suitable switches directly operated by the controller sheave.

A somewhat novel drum winding elevator has recently been perfected by the Sprague Company. This machine vator also uses a double winding drum, geared by a single worm to a C. & C. bi-polar compound motor. The band brake is located between the gears and the motor and is operated by an electric magnet. Control is effected by means of a rope sheave on a separate shaft connected to a main and reversing switch, the operation of which closes the line and reverses the armature connections and also connects a solenoid which controls the resistance in series with the motor.

As has been stated, the starting of electric motors under heavy loads, which frequently occurs in direct connected electric elevators of any type, is accompanied by a rush of current through the armature which gradually decreases as the motor increases its speed. In order to prevent injurious effects from this to the electrical and mechanical apparatus, and jerky and sudden starts, it has been necessary to provide compound windings and various slow-starting and resistance devices.

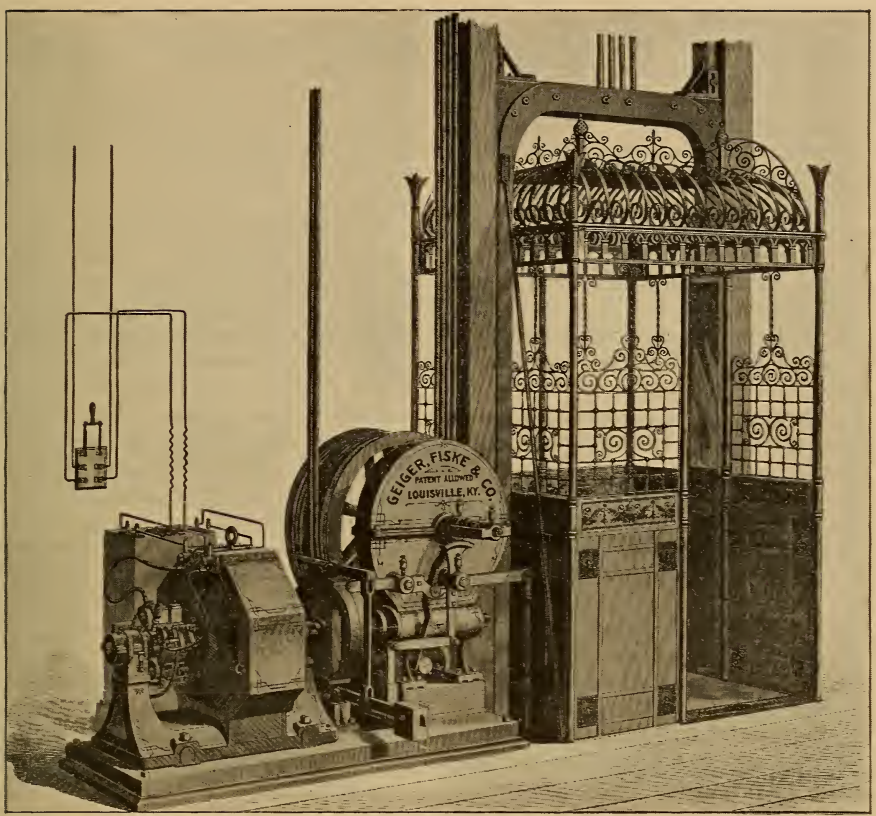


ANOTHER DIRECT-CONNECTED ELEVATOR WITH KEYSTONE MOTOR.

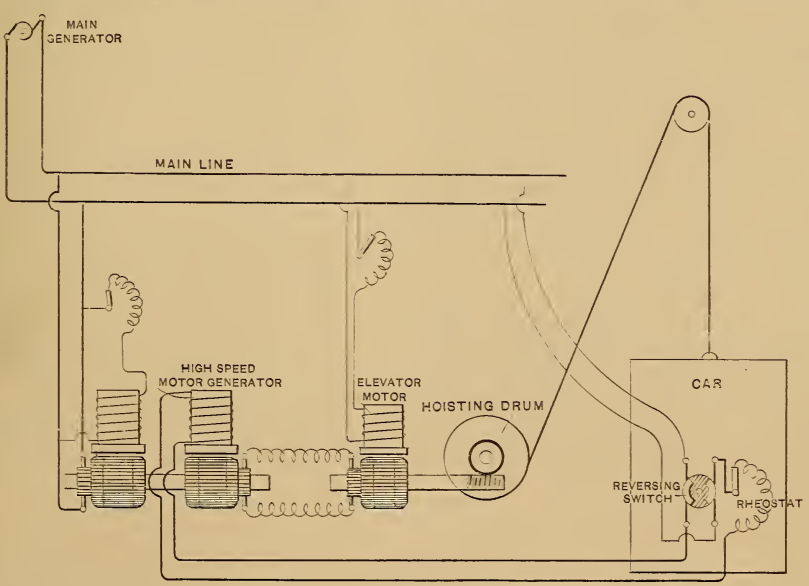
Various methods have been devised for starting without any great loss in resistances and rush of current.

Messrs. Geiger, Fiske & Co., of Louisville, Ky., make an electric elevator in which the motor is started without any load, and as it gradually attains its normal speed a clutch between the motor and drum gearing is thrown into action. The elevator is of the single drum type, operated by internal spur gearing, the pinion being operated by a worm from the motor shaft. Control is effected by means of the usual rope sheave connected to the brake and motor regulator.

In the Leonard method of elevator control, sometimes installed by the Otis company, the elevator motor is supplied with current from a separate dynamo and is controlled by apparatus directly affecting the latter. The motor and dynamo armature brushes are permanently and directly connected, and the voltage and amount and direction of the current generated and supplied to the motor are regulated by a resistance in the fields of the generator which is operated by a constantly running motor. The diagram on the opposite page shows the connections and general arrangement of this method of control. The motor-generator works at high speed in order to decrease weight and size. The motor is shunt wound, with a resistance in its fields to vary the speed. Its fields are separately excited from the supply line. The terminals from the line and also from the generator fields are brought to the elevator car where, by means of a reversing switch and rheostat, the polarity and strength of the generator field can be altered, consequently varying the direction and strength of the generator current and voltage, which, being directly supplied to the armature of the elevator motor, causes corresponding changes of speed and direction of rotation in it.



ELECTRIC ELEVATOR BUILT BY MESSRS. GEIGER, FISKE & CO., LOUISVILLE, KY., U. S. A.



THE LEONARD SYSTEM OF ELECTRIC ELEVATOR CONTROL.

The advantage of this method consists in varying the voltage supplied to motor with the speed desired. In starting, or when operating at low speeds, the voltage is very low, but as the resistance is also small, the current will be quite large and give the necessary starting power. Increasing the voltage increases the speed of the hoisting motor. In this way the electrical energy supplied to the motor is always proportional to the work being done. No power is lost in series resistances and the speed can be most accurately controlled.

Drum winding elevators can also be operated similarly to the Sprague machine, in which the motor works only in hoisting, while the descending car operates the motor as a dynamo. Plans have been developed for charging storage batteries or sending current back into the supply line in this way, but it is doubtful if such arrangements have any practical value as compared with the counterbalance method.

A number of other commercial electric elevators could be described, but their general plan is similar to those already mentioned. There can be no question that these or some of their modifications will eventually supersede the hydraulic machine. While each of the types possesses special features and advantages, the electric elevator, generally considered, has various elements of superiority over the hydraulic machine. Particularly prominent is the already mentioned flexibility and ease of installation which, with the general introduction of the electric current, distributed from central stations, become still more striking.

But the installation of a complete, isolated electric elevator plant, including boiler, engine and dynamo, also presents advantages, especially where the current can be used for lighting purposes also. The economical operation of such a plant, as compared with a hydraulic elevator outfit, becomes principally a question of the efficiency of the generating plant. Ordinarily the efficiency of a drum-winding electric elevator, from the electrical energy at the motor terminals to the work done by the lifting cables, is from fifty to sixty per cent.

This efficiency is about the same as that of the hydraulic machine. As the steam generating apparatus in both cases may be the same, it becomes a question between using steam in a pump cylinder to produce hydraulic energy at the other end, or using it in a modern high-class engine cylinder to produce electrical energy at the dynamo terminals. Generally considered, it would seem that the latter had the advantage, but the writer has been informed by a prominent hydraulic engineer that a hydraulic installation of the best design can equal an electric plant.

Even though this be a fact, and both installations have the same efficiency, from the coal consumed to the work done by the elevator car, the collateral advantages alone of the electric outfit would warrant its installation. In assuming, however, that the two are equally efficient, we are considering that both work with loaded cars. Whether loaded or empty, it matters but very little in the hydraulic machine, as the cylinder always takes the same amount of water, although in some machines the cylinder is arranged to use either all or one-half of the full amount. The actual average efficiency of the hydraulic machine would, therefore, compare very poorly with that of the electric plant in which the motor consumes energy only in proportion to the work required. The hydraulic machine, it is true, takes water power only one way, yet this is always sufficient to meet maximum requirements. Besides, the advantages of counterbalancing are best realized in the electric elevator.

THE COST OF STEAM POWER.*

By Chas. E. Emery, Ph. D.

"The Cost of Steam Power," as discussed here by Dr. Charles E. Emery, and "The Cost of Water Power," treated of by Samuel Webber in the article following, are subjects in which every power user is vitally interested. Particularly true is this because of the remarkable development in recent years of electric power transmission projects and the growing tendency to utilize water fall energies which hitherto have been allowed to run to waste. While both articles have been prepared with the special consideration of American market conditions, they are none the less valuable to engineers everywhere.—THE EDITOR.

SECTION 1. In connection with the proposed supply of power in large units from Niagara Falls and other undertakings of a similar character, the question naturally arises: What would be the cost of steam power if also supplied in large units and generated with modern machinery of the most approved type? The question would be a simple one if it involved only the amount of coal consumed at a definite price, and the labor required to handle the coal and attend to the machinery. It is very common to compare the value of two engines simply by the relative amount of coal consumed, assuming that other costs incident to the development of the same power will be the same in all cases. Even if the assumption be substantially correct, it has a more important bearing on the result than appears at first sight. The cost of coal is for ordinary engines of moderate size only about one-third of the total cost of steam power, so, if the other costs remain nearly constant, moderate savings in the cost of coal will not proportionally decrease the cost of the power.

SEC. 2. In large plants operated nearly at full capacity, the best types of steam machinery can be profitably employed, the cost of superintendence will be reduced and the cost of labor required for operation materially decreased. The decrease in labor depends largely on the size of steam unit it is found practicable to employ. Triple compound engines of 10,000 to 15,000 horse-power each are used quite successfully in large ocean steamers, but it is considered that these units are altogether too large for the problem we are considering.

SEC. 3. Any supply of power must be adapted to the nature of the demand, which for most industrial operations is variable, and it is desirable to make the steam units of such size that one or more of the same can be grouped together to carry the load at any time without either overloading or greatly underloading either of such units. In a large plant, upon which presumably many different manufactories depend for power, there should be a spare unit which can be used in case of accident and ordinarily employed in regular turn so that all the machinery can be kept in repair.

SEC. 4. It will thus be seen that the size of the units is limited by the conditions above stated. If 20,000 horse-power as a maximum were to be delivered, two units of 10,000 horse-power each would do the work, but evidently the spare engine would require also to be 10,000 horse-power and this would involve too large an amount of capital in spare machinery. At Niagara Falls three connected turbines and dynamos of 5000 horse-power each are being erected in a preliminary plant so that only 15,000 horse-power maximum can be delivered if the principles above outlined are strictly carried out, but it is probable that one unit will be practi-

* From a paper read before the American Institute of Electrical Engineers, June, 1895.

cally kept in reserve and more units added as the demand warrants. With steam power there would be some advantages for a 20,000 horse-power plant in adopting a unit of 2500 horse-power, on which basis, with one spare unit of this size, there would be nine such units in all. There is an advantage in having all the engines alike, as the parts required for repairs are then duplicates of each other, the units can be more suitably arranged in the building and the labor better distributed. When it could be done without too much detail, it would be desirable to couple together several engines of 2500 horse-power each, so that they would be capable also of independent operation. Another method would be to disregard absolute uniformity when so much power is to be delivered and have several duplicates of two different units, say one of 2500 horse-power and another of 5000 horse-power, which would either require the size of the spare engine to be increased, or that the other engines be slightly overworked in case of accident. For simplicity, however, all the costs will be assumed alike with either arrangement.

SEC. 5. The average cost per horse-power when the load is variable is considerably greater than if the power be furnished continuously. Coal is wasted in building up the fires and in caring for them when not required, all supplies are increased from the necessity of starting new after every stoppage, and there is an important loss due to the interruption of the regular hours of labour. A sufficient force must be kept on hand at all times to provide for any demand and the watches of the men arranged in some practical way so as to proportion the labour to the work to be done as nearly as possible.

SEC. 6. It is desirable at the outset, however, to ascertain what steam power will cost under the most advantageous conditions as to demand, and we therefore submit a preliminary estimate based on the assumption that 20,000 horse-power can be sold for every hour in the year. The details of the estimate are discussed afterward.

SEC. 7.

TABLE I.*

SHOWING COST OF STEAM POWER ON BASIS OF GENERATING 20,000 HORSE-POWER CONTINUOUSLY EVERY HOUR IN THE YEAR.

			Per cent. of total cost.
	Yearly cost of coal for 20,000 net horse-power operated continuously every hour in the year, based on a consumption of 1.25 pounds of coal per indicated horse power per hour, Sec. 10. Cost of coal assumed at one mill per pound, or $2.24 per ton.		
1.	Sec. 11. Engine efficiency assumed at 92.3 per cent., Sec. 10	$237,250	43.7
2.	Estimated cost of labour, Sec. 12	60,444	11.1
3.	Estimated cost of supplies and regular repairs, Sec. 13	105,120	19.2
4.	Estimated interest, insurance, taxes and cost of renewals, Sec. 14-15	144,000	26 3
5.	Total	$546,814	100.0
	Which divided by 20,000 gives the following:		
6.	Cost of steam power per horse-power per year, on basis of 20,000 horse-power delivered every hour in the year	$27.34	
7.	Cost of steam power per horse-power per year on above basis, if 5 per cent. of the original cost of plant, Sec. 15, be charged for dividends, and $1 per horse-power added for general business expenses, Sec. 17—27.34 + 3.60 + 1.00 =	31.94	
8.	Cost of steam power per horse-power per year on above basis, if 10 per cent. of the original cost of plant, Sec. 15, be charged for dividends, and $1 per horse-power added for general business expenses, Sec. 18—27.34 + 7.20 + 1.00 =	35.54	

SEC. 8. This cost is, for reasons which will be discussed later, lower than it is probable any plant can be operated under commercial conditions. This price is somewhat higher than those given in the papers previously mentioned, simply because operation is supposed to be continued every hour in the year.

SEC. 9. The cost of coal above outlined is derived as follows: The best triple compound engines have developed a horse-power for a little less than 12 pounds of water per horse-power per hour, and boilers have been constructed which at actual pressure from actual temperature of feed, evaporated 10 pounds of water per pound of first quality coal. Both these results are under experimental conditions, but we must assume that in a large plant, like this, all details will be so well attended to that fair experimental results may be obtained all the time.

* In going over Dr. Emery's figures, it will be well for English readers to bear in mind that the American dollar is equivalent to four shillings.

We therefore assume that the power be produced regularly, for 1¼ pounds of coal per indicated horse-power per hour, which would be obtained with engines requiring 12½ pounds of feed-water per horse-power if the boilers evaporated 10 pounds of water per pound of coal, or if the boilers evaporated 9.6 pounds of water per pound of coal and the engines only required 12 pounds of water per horse-power per hour.

SEC. 10. For permanent work of the kind assumed, engines of comparatively slow speed should be selected and, although some of the work might be directly connected, part of it at least would necessarily be operated by some method of transmission. The frictional losses of the engines and the more important features of transmission to the work done have been assumed at 7.69 per cent., so that the amount of coal per indicated horse-power above assumed must be increased by $\frac{1}{13}$ to give the coal per net horse-power.

SEC. 11. The cost of coal per ton varies greatly in different parts of the country. The actual cost of mining bituminous coal is as low as 25 cents per ton in some locations and the coal can be delivered on the cars at a good profit at 50 cents per ton. At deep mines the cost of mining is greater, but in all cases the principal cost of coal is the transportation, which has been reduced from time to time by increasing the size of the coal cars and the weight of the train, and by reducing the grade in the direction of traffic, until it is credibly stated that coal can be hauled on the main trunk lines, at a profit, for one half cent per ton per mile, thus adding only 50 cents per ton for each 100 miles of haul. The lateral roads with undulating grades cannot haul coal at as low a rate as this. There is, moreover, to be added the general selling expenses, so it has been assumed that along the lakes, although comparatively near coal mines, the best quality of coal will cost but little over $2 per ton if purchased in large quantities, though this price must be increased on the seaboard fully 75 cents, and for ordinary consumers, of course, much more. The price upon which comparison has been made is one mill per pound or $2.24 per ton, to include the cost of delivery directly in front of the boilers. The cost in line 1, Table I, is derived simply by multiplying the net power, 20,000, by 1¼, the coal per indicated horse-power, adding $\frac{1}{13}$ to allow for friction, and multiplying the result by 8760, the number of hours in the year, and $0.001, the price per pound. The next item, that of labour, is made up as follows :

SEC. 12. Without attempting to arrange watches, it is assumed that on the average there would be required in such a station at all times.

One attendant for each 2500 horse-power engine, or 8 men in all, at 25 cents per hour	$2.00
Fourteen firemen and 3 additional men at the same pay to care for pumps, etc., and to keep the premises clean; total, 17 men at 20 cents per hour	$3.40
Total cost of labour per hour	$5.40

There would also be required a chief engineer, 3 assistant engineers and some clerical help, which, under the head of superintendence would cost, say, $13,140 per year, or $1.50 per hour, making a total of $6.90 per hour. The total cost for labour and superintendence for one year of 365 days, or 87600 hours, at $6.90, is $60,444 as given in line 2 of Table I.

SEC. 13. The cost of supplies and repairs in connection with the boilers and large condensing engines in the cotton mills of Fall River proved, upon investigation several years ago, to be approximately $\frac{8}{10}$ of a mill per horse-power per hour. With the hope that this cost can be reduced in an immense plant of this kind, the quantity in line 3 has been extended on the basis that the cost will be only 0.6 mill.

20,000 horse-power × 8760 hours × $0.0006 = $105,120, as writen in line 3 of Table I.

SEC. 14. The above estimates provide only for regular repairs. Independent of this a certain percentage of the first cost should be put at interest every year to provide for renewals of the machinery and provision made also

for paying taxes and insurance. Calling these three 5 per cent. of the cost, and considering that a company which can build so large a plant can possibly borrow money at 5 per cent., 10 per cent. of the total cost will be required for these several items.

SEC. 15. The total cost of such a plant cannot be determined accurately in advance. The present prices for steam machinery are very low and it might be possible to buy engines of the best type with necessary boilers, ready for erection, for $30 per horse-power. To this price, however, must be added the cost of the land upon which the plant is to be erected, the cost of foundations, of erection of the buildings, of the chimney, the pipe connections, the general means of transmission, and the multitude of minor details required for fitting up such a place ready for use. The probable cost has been fixed at $64 per horse-power and as at least 1/8 surplus power will be put in the station, there will be required a steam plant of 22,500 horse-power, which, at $64, will cost complete $1,440,000, 10 per cent. of which, as required above, is written in line 4, Table I.

SEC. 16. Referring to line 6, we find that the "Cost of steam power per horse-power per year on the basis of 20,000 horse-power delivered every hour in the year" is $27.34. The price at which this power can be sold to consumers will depend upon the way the company furnishing the power is organized. The interest on the cost is already provided for in line 4, so the net cost given, viz: $27.34, would be that chargeable to power, if the same company that built the works used the power, or if an association of individuals should build the plant and simply charge themselves with its cost.

SEC. 17. If, however, a private company with ample means should build the plant on a cash basis and wish to sell power and realize a return of 5 per cent. on first cost, independent of interest on the money invested, the modified cost would be $27.34 plus 5 per cent. of $(64 \times 1\frac{1}{8}) = \$72$ (Sec. 15) viz. $3.60, to which should be added, say, $1 per horse-power for general business expenses, making the total charge $31.94 shown in line 7, the same method being used in reference to similar lines in Tables II. and III.

SEC. 18. If, however, the promoters desired 10 per cent. profit on the original cost or a proportionally less percentage on stocks and bonds issued in excess of first cost, the modified cost per horse-power per year would be $27.34 plus 10 per cent. of $72, (Sec. 15) viz. $7.20, to which, adding $1 per horse-power, as before, for general expenses, gives as the total charge under these conditions $35.54, shown in line 8, the method applying to Tables II. and III. as above explained.

SEC. 19. We are now prepared to ascertain the variations in result which would be produced if the power were considered variable. For this purpose let us assume there will be sold :

	H. P. Hours.
1. 20,000 horse-power, 10 hours per day	200,000
2. 12,000 horse-power, 10 hours per day	120,000
3. 5,000 horse-power, 4 hours per day	20,000
4. Total daily horse-power hours	364,000

which would probably be required on, say, 309 working days in the year.

5. Total horse-power hours, 309 days	105,060,000
Then, if 5000 horse-power were required for the remaining 56 holidays in the year:	
6. Total horse-power hours, 56 days of 24 hours, 5000 horse-power	6 720,000
7. Total horse-power hours per year	111,780,000
Average horse-power per hour during the year:	
8. Previous result + 8760 =	12,760 H. P.

The average horse-power is therefore 63.80 per cent. of the maximum. This percentage is frequently termed the "power factor," and is rather higher than has been found in practical cases heretofore. An estimate of the cost on this basis is given in Table II.

SEC. 20. The cost of coal is made up as follows : By reference to section 19 it will be seen that 15,000 horse-power of boilers out of 20,000 must be shut down daily for periods varying with the demand, and it is considered that it will require an amount of coal equal at least to the average consumption for one hour during regular operation, to maintain banked fires, overcome radiation, and bring the fires to average working

condition when they are again put in operation. The total daily horse-power hours in line 4 is therefore increased 15,000 and multiplied by 309; the horse-power hours for the 56 holidays, line 6, are then added to the same; the sum multiplied by 1.25 pounds of coal per horse-power and by one mill per pound and one-twelfth added to the whole for friction, which gives the result in line 1, Table II.

SEC. 21.

TABLE II.

SHOWING THE COST OF STEAM POWER ON BASIS OF GENERATING 20,000 HORSE-POWER MAXIMUM AND AN AVERAGE OF 12,760 HORSE-POWER FOR EVERY DAY IN THE YEAR.

			Per cent, of total cost.
1.	Yearly cost of coal, Sec. 21	$157,644	37.3
2.	Estimated cost of labour, Sec. 22	47,652	11.3
3.	Estimated cost of supplies and regular repairs, Sec. 24	73,584	17.4
4.	Estimated interest, insurance, taxes and cost of renewals, Sec. 25	144,000	34.0
5.	Total	$422,880	100.0
	Which divided by 12,760, the average horse-power, Sec. 19, gives the following:		
	Cost of steam power per horse-power per year on basis of delivering 20,000 horse-power maximum and an average of 12,760 horse-power for		
6.	every day in the year		$33.14
	Cost of steam power per horse-power per year on above basis if 5 per cent. of the original cost of plant be charged for dividends and $1 per horse-power added for general ex-		
7.	penses, Sec. 17, 33.14 + 3.60 + 1.00 =		37.74
	Cost of steam power per horse-power per year on above basis if 10 per cent. of the original cost of plant be charged for dividends and $1 per horse-power added for general expenses, Sec. 18, 33.14 + 7.20 +		
8.	1.00 =		$41 34

SEC. 22. The labour cannot be distributed accurately until the variations of loading are developed practically. On any definite basis, such as is assumed in section 19, the watches could be arranged so that there would be little loss of time, but in practice there would be a variation of load at the same hour on different days. For instance, with the electric lighting part of the load, the demand would vary with the weather; so, to be provided for unexpected demands, there must be a surplus of labour. Such surplus will be assumed at 20 per cent. for the 14 hours of reduced power per working day, shown in Section 19, lines 2 and 3, equivalent to labour for 28,000 horse-power hours per day, or 8,652,000 horse-power hours for 309 days. Adding only 10 per cent. for 56 holidays gives 6,720,000 × 11 = 7,392,000 horse-power hours. Adding both to the total horse-power hours, Sec. 19, viz.: 111,780,000, gives a total for the year of 127,824,000 horse-power hours, which at $0.00027 per horse-power per hour (= $5.40 ÷ 20,000) easily derived from Sec. 12 gives:

Cost of labour per year	$34,512
Cost of superintendence per year from Sec. 12.	13,140
Total for labour and superintendence per year as written in line 2, Table II	$47,652

SEC. 23. The cost of labour and superintendence above is 100 × $47,562 ÷ 60,444 = 78.83 per cent. of that required for full operation throughout the year, shown in Table I., although the average power developed is only 63.80 per cent., Sec. 19.

SEC. 24. The cost of supplies and regular repairs, line 3, will be somewhat greater proportionately than for continuous operation, and is estimated to be 70 per cent. of the similar costs given in Table I., $105,120 × 0.70 = $73,584, which is written in line 3, Table II.

SEC. 25. Evidently the interest, insurance and taxes embodied in line 4, Table I, are not modified, and the percentage allowed for renewals is so small as not to materially affect the result, so the amount given in line 4, Table I., is repeated in same line of Table II.

SEC. 26. The presentation in Table II. will give a fair idea of the prices it would be necessary to secure on installing a large steam plant to furnish power in various quantities to consumers on the premises, or to apparatus for transmitting power to the same, the costs of which transmission are not included.

SEC. 27. A large proportion of the power in manufacturing establishments is used only ten hours per day, so an estimate is made in Table III. on this basis.

SEC. 28. The yearly cost of coal, line 1, Table III., is obtained by computing the coal for 11 hours per day, for reasons explained in Sec. 21 and making the calculations explained in the latter

part of Sec. 11 for 309 × 11 = 3399 hours in the year.

SEC. 29.

TABLE III.

SHOWING THE COST OF STEAM POWER ON THE BASIS OF GENERATING 20,000 H. P. CONTINUOUSLY FOR 10 HOURS PER DAY FOR 309 DAYS IN THE YEAR.

		Per cent. of total cost.
1. Yearly cost of coal, Sec 29	$92,056	30.6
2. Estimated cost of labour, Sec. 30.	27,198	9.1
3. Estimated cost of supplies and regular repairs, Sec. 31	37,080	12.3
4. Estimated interest, insurance, taxes and cost of renewal, Sec 32.	144,000	48 0
5. Total	$300,334	100.0
which, divided by 20,000, gives the following :		
6. Cost of steam power per horse-power per year on the basis of delivering 20,000 horse-power continuously for 10 hours per day for 309 days in the year	15.17	
7. Cost of steam power per horse-power per year on above basis if 5 per cent. of the original cost of plant be charged for dividends and $0.75 per horse-power added for general business expenses, Sec. 17----15.17 + 3.60 = 18.77 ; 18.77 + 0.75 =	19.52	
8. Cost of steam power per horse-power per year on above basis if 10 per cent. of the original cost of plant be charged for dividends and $0.75 per horse-power added for general business expenses, Sec. 18----15.17 + 7.20 = 22.37 ; 22.37 + .75 =	23.12	

SEC. 30. The labour would be occupied 309 working days, and, say, one-half the holidays, Sec. 19. The cost of labour for 337 days, of 10 hours, or 3370 hours, at $5.40 per hour, Sec. 12 = $18,198. Two assistant engineers could be dispensed with, compared with Sec. 13, thus reducing the cost of superintendence to say, $9,000 per year. The sum of these two quantities is written in line 2 of Table III.

Sec. 31. The cost of supplies and repairs is estimated at the rate of 0.6 mill per horse-power as per Sec. 13, 20,000 × 3090 × $0.0006 = $38,080, as written in line 3, Table III.

SEC. 32. The amount written in line 4, Table III., is the same as for the two other cases. The cost of renewals should apparently be reduced as the machinery operates less hours, but the percentage allowed for renewals is very small and should be increased for the other cases rather than reduced for this. Moreover, renewals are made more frequently on account of new discoveries or changes in business than from the actual wearing out of the apparatus.

SECTION 33. The prices given in lines 6, 7 and 8 of Table III. will best compare with those carried familiarly in the mind. The corresponding price from a previous paper by the writer (Trans. El. Engrs., 1893) is $23.31 per H. P. per year under conditions which compare with the $18.77 stated in line 7, Table III. The previous calculations were made on a basis of 500 H.P. units, so that the difference, viz., $3.54 per H. P., represents a saving of 15 per cent., due to generating the power on the larger scale. The prices herein given are as low as it would be safe to expect with very careful management of a very large plant. The comparatively small difference in result is due to the influence of the constant cost shown in line 4 of the several tables. It forms 26.3 per cent. of the total cost for 20,000 horse-power every hour in the year., Table I ; 34 per cent. for variable power, 20,000 horse-power maximum, 12,760 horse-power average day and night, and rises to 48 per cent. for 20,000 horse-power during 10 hours of the ordinary working days in a year. The cost of coal is respectively 43.4 per cent., 37.3 per cent. and 30.6 per cent. of the total cost for the same three conditions. The fixed charges also increase greatly the cost of water power, as the writer has had occasion to call the attention of parties engaged in these large hydraulic enterprises.

SEC. 34. It should be borne in mind that if water power, or power derived from water, be sold on a 24-hour basis, but can only be utilized during 10 hours per day, the cost of the water power direct or derived should be compared with the cost of steam power on a 24-hour basis in Tables I. or II., but with that of steam power on a 10-hour basis in Table III.

SEC. 35. It should also be borne in mind that all these estimates provide for fixed expenses, such as interest, insurance, taxes and cost of renewal, and that in comparing the prices above given with the cost of water power, similar expenses should be added to the price of such power, based on the

cost to the consumer of installing the water power or the mechanism through which the power is derived. For instance, manufacturers located on the canals of large water power companies necessarily build their own head and tail races and wheel pits and install the gates, screens, turbines and means of transmission for utilizing the power. This when well done in many locations cost as much to install as a steam plant, so the fixed annual charges for this item would be $5.00 or $7.00 per horse-power, which, together with cost of labour and supplies, must be added to the cost to be paid for the water power in order to compare with the cost of steam power as presented in the tables of the writer.

SEC. 36. When power is electrically transmitted, the consumer is generally required to pay for the electric motor, the general means of transmission therefrom and some incidentals. The cost of this work, together with the portion of the building and even of the real estate occupied, should be considered in the same way as has been done above, and at least 10 per cent. of such cost, together with actual cost of labour and supplies, added to the tendered price of net power delivered in order to compare the cost of steam power shown in the various papers of the writer, which are written on the basis that a manufacturer should receive a profit on the money expended in plant as well as that expended in his business. If interest is left out in one case it should be in the other, and is already included in the tables.

SEC. 37. The last column of the several tables furnishes a ready means of eliminating either of the items of cost desired. For instance, in Table III., which is on a 10-hour basis, we find in line 4 that the "estimated interest, taxes and cost of renewal" is 48 per cent. of the total cost, which cost to the parties using the power is in such table $15.17 per year, line 6. The cost of steam power per horse-power per year from large units for 10 hours per day, without considering the above items, is therefore, only $0.52 \times \$15.17 = \$7.89$, which is the cost to be compared with the price of power from an external source when the items above referred to are excluded in each case as they are in the popular discussion of the subject.

THE COST OF WATER POWER.

By Samuel Webber.

ALTHOUGH the value of a water horse-power is as variable as almost anything in business can be, depending on location and demand, the subject is worth examination, and some of the various opinions in regard to it may be well considered, and the data and arguments quoted.

It has been a generally accepted statement that a water power was worth what it would cost to supply the same amount of steam power, its only competitor, at any given point. This seems to be the only reasonable mode of determining its commercial value at present and depends, to a large extent, on the cost of coal at the point where the power is to be maintained or applied, as combustion of fuel is the only other practicable source of power.

To ascertain this relative value there are to be taken, on the one hand, the cost of dam, canals, wheels and other accessories at a fair allowance for interest and depreciation, adding cost of attendance, of oil and repairs, as against the cost of a steam plant under similar charges, plus the cost of fuel.

There should also be taken into consideration the height of the waterfall, the uniformity of flow of the stream and the minimum supply in the dry

seasons; but extraneous questions should be avoided, such as cost of transportation of materials and supplies, value of low pressure steam for heating purposes, demand for water for other purposes, and social and sanitary conditions affecting the supply of operatives. These it might be necessary to consider, were the question simply confined to the value of a water power for spinning cotton, say, in the interior of New England, in the United States, as compared with a steam power for the same purpose on the seaboard, or near the coal mines; but they have nothing to do with the value of a water power for the many other purposes for which it is required, such as working wood or iron or furnishing power for the generation of electricity.

A number of very ingenious estimates have been published to show that steam was cheaper than water power, but the data upon which they were based are, to a great extent, misleading, as the cost of water power is based on the enormous extra expenditures at Lowell, in Massachusetts, in the great American water power district, and at other cities, to secure all the water in the rivers except in the few days of "spring freshets," when the snow is melting.

These expenditures at Lowell have resulted in the placing of 23,000 horse-power turbines, according to the "Lowell Year Book" for 1889, instead of the 10,000 for which the supply was originally calculated.

On the other hand, the cost of steam power has been based on 1000 horse-power compound condensing engines, using 1¾ lbs. of coal per hour per horse-power at $3* per ton, and after making fair allowances for interest and depreciation, the cost of power is made out to be from $20 to $22 per horse-power per annum.

Such conditions as these, however, are seldom realized and the cheapest reliable data in the possession of the writer were obtained last autumn from one of the newest mills in Fall River, one of the great American steam power towns, for the months of April, May and June, 1893, when no steam was used for any other purpose than power and cross-compound engines of 650 and 1050 horse-power respectively were employed.

In this instance the coal cost $3.70 per ton. The consumption in the 1050 horse-power engine for power only was 1.99 lb. per hour and the total cost, including interest on the original investment, was $21.13 per horse-power for steam delivered to engine, or, adding 10 per cent. for loss in engine, $23.24 per net horse-power delivered. For the 650 horse-power engine the cost was higher, the consumption of coal being 2.33 lbs. per hour per horse-power, the cost of plant, $42,000, and the net expenses, made up in the same way, $26.31 per horse-power delivered.

These, as I have said, are the lowest figures I have on record and are far below the ordinary cost of steam power in regions where there is water power available. Data gathered by the writer twenty years ago from mills using Corliss engines, with boilers of good construction, some of them as good as we can get to-day, gave for actual running expenses, for power and heating, not including interest on plant or any charges of any kind, $47.10, $55.12, $52.70 and $44.16, the last engine being 50 per cent. larger than the others and the high cost of $55.12 being due to extra cartage of coal from the wharf, all the mills being on the seaboard. If we average these we get $50.04, from which we may deduct one-quarter for heating, leaving for the net power $37.53. If we add the same quarter for interest and sinking fund, these plants having probably cost an average of $100 per horse-power, we get $50 per horse-power, which has been the common value of a horse-power, either for steam or water, in New England generally, though the charges in cities have often been much higher.

It has been necessary to dwell somewhat at length on the cost of steam in the first place, as it has been said above, the only competitor by which the value of water power has been determined,

*English readers will find it convenient to bear in mind that the American dollar is equivalent to four shillings.—THE EDITOR.

and as the actual cost of the latter is so varied by the conditions under which it is developed.

The figures given me by various friends amply confirm, and are confirmed by, my own observations and calculations, and show such differences in the cost of steam power as to justify me in saying again that the old rule is correct and that the value of water power in any given locality is what it would cost to replace the water power by steam on the same spot.

We will now turn to the actual cost of water powers in various American localities, and, although most of the large ones in the eastern part of the United States were developed so many years since that no man now living remembers all about it, there are data in existence from which we may arrive at some approximate results. I find at Lowell, among the papers of the Locks and Canals Company, the following records: "The Merrimac Manufacturing Company was incorporated the 5th of February, 1822. On the 27th of February a board of directors was chosen, to whom was transferred the property which had been previously purchased by Messrs. Lowell, Appleton, Jackson, Boott and Dutton, the originators of the enterprise. This consisted of 330 shares of the stock of the old Pawtucket Canal, built to facilitate navigation around the falls, for which they had paid 30,217 dollars, and land, for which they paid $18,330." As the canal shares were probably $100 each at par value they paid nearly full rates for them. Later on, in 1823, the enlargement of the canal and the renewal of the locks was completed at a cost of $120,000.

This was estimated to furnish fifty "mill powers," so-called, being, as described, "25 cubic feet of water per second, on 30 feet fall, or its equivalent, according to the height of the fall." This was taken from the water required to operate the first mill at Waltham of 3584 spindles, with all the other machinery for making cloth. This amount of water would give 85 gross horse-power, and, if the wheels gave 70 per cent. net effect, would produce 59.335 horse-power in the mill. This was called a "mill power," commonly stated "at about 60 horse-power," and this term, for this quantity of water and power, came into general use throughout New England.

These 50 "mill powers" of 60 horse-power each, at $120,000, represent a first cost of $40 per horse-power for land and water. The price for these, for sale, was fixed at $4 per spindle, or $14,336 for a mill power, of which $5000 was not paid, but remained on interest at 6 per cent. per annum, as "water rent," and this round sum of $15,000 per annum was equal to 12½ per cent. on the original investment. The amount paid down, $9,336, covered the lands taken for mill sites and other buildings of various kinds.

Such is my recollection of the matter, dating from 1841, when I first went to Lowell, and derived from the men who began with the enterprise, although some of the younger engineers who have been writing of late years on the cost of steam and water have seen fit to add to the cost of the water the amount paid for mill sites.

This charge of $5 per annum per horse-power or nearly so, was adopted at the American water power cities of Manchester, Saco, Lewiston, Holyoke and Lawrence, and even down at Augusta, Ga., where the city, which built the canals, has furnished water to the mill owner at the same rate. Mr. James B. Francis, the veteran hydraulic engineer, gave me, many years since, the drainage area above Lowell as 4090 square miles, and the flow of water as follows :—In the spring, with high water, 90 cubic feet per minute per square mile of area ; low water flow, 30 cubic feet per square mile ; available flow (but due to storage), 55 cubic feet per square mile.

A flow of 30 cubic feet per minute would, on a 30-foot fall, give a gross horse-power of 7480, and if the wheels netted 70 per cent. 5256 horse-power available. The dam, however, held back the night flow to above Nashua, or 17 miles, and as the mills in those

days were operated for about 13 hours the total water available was 5256 plus $\frac{11}{13}$ of 5256, or 4447, or, in all 9703 horse-power.

This was sufficient, until about 1846 when this flow was exhausted, and it was deemed advisable to build larger canals and utilize the water which "ran by" during many months of the year. The new "Northern Canal," built in 1846 and '47, cost $510,000, and the old breast wheels, which had probably not netted over 60 per cent., instead of 70 per cent. as estimated, were taken out, and Boyden or Fourneyron turbines were substituted. These gave from 75 to 80 per cent. net effect from the water, and, with the saving of the new canals and the storage of the water in spring, have brought the water-power at Lowell up from 9000 to 19,000 horse-power, available part of the year. The Boyden turbines were, however, expensive, and all the work connected with them, including wheel pits, was done in the most massive and substantial manner so that the cost of a horse-power at Lowell, growing up and changing as it has, is no criterion for the legitimate cost of a horse-power to-day under any fair circumstances.

Mr. J. B. Francis once told me that the cost at the Booth Mills, at Lowell, for the wheels, feeders, pits and races on a 19-foot fall was $100 per horse-power. At the same time when these enlargements began it was found that almost all, if not quite, of the mills were using much more water than was conveyed to them by the original deeds. and a system of daily "flume measurement" was adopted, and extra rates were charged for "surplus water" as follows: $2 per day per mill power under an excess of 40 per cent.; $10 per day for an excess over 40 per cent. and under 50 per cent., and $20 per day for an excess over 50 per cent.

Nearly the same scale was adopted at Lawrence, where the original rates were the same as at Lowell, and when the new canal was cut on the south side of the river the new leases were raised to $1200 per annum per mill power instead of $300. The original cost at Lawrence for the dam was $250,000, and the north canal cost about the same, making $500,000 for 10,000 horse-power, or $50 per horse-power. To this must be added the cost of the south canal, $125,000 more. It was originally intended to build the city on the south side of the river where the ground was much more level, but an agent employed by the projectors to purchase the land for them, reserved so much of the most valuable portion of it for his own use that the plan was changed, and the first canal was dug on the north side of the river at double the cost necessary on the other side. The south canal was afterwards cut to make the land on that side saleable, but either one would have used all the power. Had the southern plan been adopted, the first cost would have been only $37.50 per horse-power for the water plant.

There are a few more words that should be said. The cost of the dam at Lawrence, $250,000, was due to its construction at the foot of a long rapid. The new dam at Manchester, N. H., controlling the same horse-power, *i. e.* 10,000, was built equally well of dressed stone and cement in 1871 at the head of the fall and cost $60,000.

The fall at Manchester is 49 feet, and is used on two levels of 21 and 28 feet respectively, and though no record is obtainable the cost of the canals may be safely assumed at not over $200,000, which would bring the total expenditure for the dam and canals to $26 per horse-power. The writer made the following estimate a year ago of the probable cost of a 5000 horse-power water plant on a 20-foot head:

Dam near head of falls, 10 ft. high, 10 ft. wide at base, 5 ft. at top, average width 7½ ft.=75 cubic feet per foot of length (500 feet)=1390 cubic yards. This, at $20 per yard (ashlar in cement), would cost $27,800. To this add 50 per cent. for guard gates and waste weirs, making $41,700. Canal, 1 mile long, 12 ft. deep, 120 ft. wide at upper, and 80 ft. wide at lower end, averaging 100 ft. = 257,000 cubic yards at 25c. per cubic yard, exca-

vations, $64,250. Add facing canal walls with stone, 1 ft. thick=4280 cubic yards, at $5 per yard, $21,400, and you get a total for dam, gates and canals of $127,400, or $25.48 per horse-power, or about what I have allowed for cost at Manchester.

If we allow as much more for land purchase and flowage rights, we get a final cost of $51 per horse-power, and, adding for wheels, pits and races, a fair estimate of $46 per horse-power for 200 feet distance from canal to river, we get a total investment of $97 per horse-power, which I take to be an ample allowance for the average under ordinary conditions. A volume on "The Water Powers of Maine," published some 30 years ago, gave the average cost in New England at $100 per horse-power for everything, and the wheels can be furnished to-day at a much lower cost.

These estimates are fully confirmed by the exact items of the cost of a newly developed water-power in New England which are reliable. The wheel plant is not completed, but the other accounts are closed. The dam was expensive, being built near the foot of the fall.

Average horse-power obtained on 22-foot fall	5,000
Minimum power obtained	3,300
Cost of Land and Flowage Rights	$ 20,000
" Dam	141,015.17
" Guard Gates	16,675.00
" Waste Weir	5,220.10
" Canal	27,362.98
Total Water Plant	$190,273.25

Or for average of 5000 H. P. $38.55 per horse-power
" Minimum 3300 " 57.69 per horse-power
Pits and Foundations for 2000 H.-P., $15,000.00, or $7.50 per horse-power.
Wheels, Shaft, Main Pulley for 1600 H.-P., $12,225, or $7.66 per horse-power.

Add these, and we get for the average power $57.75 per horse-power for total cost, and for minimum power, $78.85 per horse-power. This corroborates all my previous estimates, and gives for the minimum power an annual cost at 10 per cent. on the investment of $7.88, to which add 75 cents for attendance and oil, and we get $8.63 for the cost of a horse-power of water to-day, under fair average circumstances.

The charge of 10 per cent. I make up as follows :—

Interest on Capital	5 per cent
Depreciation of Canal and Wheel Pits	1 "
" Wheels	4 "
Average	2½ "
Repairs	1½ "
Taxes and Insurance	1 "
	10

Still farther information on this point of actual cost of water power comes from a cotton mill at Augusta, Ga., U. S. A., as furnished me by the treasurer of the company operating it.

Cost of Wheels for 1835½ horse-power	$25,000
" Pits and Races for 1835½ horse-power	25,000
	$50,000

This is for gross horse-power, and is equal to $27.24, and the city charges for water $5.50 per annum per gross horse-power. Adding to this 10 per cent. of the cost, and 75 cents for attendance and oil, gives us $8.97 per gross horse-power. As the wheels give, by actual test, over 80 per cent. net effect, the cost per net horse-power is $11.20 per annum. This is on a 42-foot fall.

Another mill in the southern part of the United States, just completed, gives me the following cost on a fall of 27 feet under very unfavorable circumstances for the construction of wheel pits, owing to quicksands :

Foundations and Pits	$55,000
Wheels (2000 H-P)	20,000
	$75,000

or $37.50 per horse-power. Allow 10 per cent. on this as before, and we have :

Water Power	$3.75
Water Rent Paid City	5.00
Attendance and Oil	.75
	$9.50

In the case of powers less than 500, the charge would be $7.00 per horse-power.

The imaginary case on which I estimated gave a cost of $97 per horse-power, on which 10 per cent. would be $9.70. Adding 75 cents for attendance and oil, we get $10.45 as the cost of my supposed horse-power, and these facts of actual cost, obtained since it was written, confirm it.

The late Mr. Samuel Batchelder, of Cambridge, Mass., U. S. A., who was one of the first cotton manufacturers of the United States, was agent of the Hamilton Mills at Lowell from 1825 to

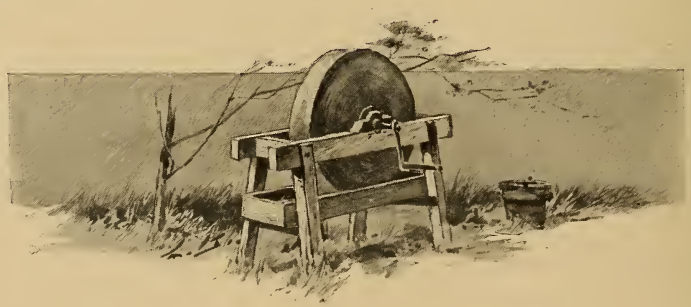
1830, and built up the York Mills at Saco, Me., said in 1856 that "the average cost of water power in Lowell, including land, was not over $15.00 per annum per horse-power, and these data corroborate his statement.

Persons owning desirable water powers need not be afraid to develop them, if coal costs over $2.00 per ton at the site; but in laying them out they should be governed by the minimum reliable flow of the stream, plus the amount that can be saved by night storage if it is only to be used for power by day, or for lighting by night, as such storage will double it. You may calculate on getting 80 per cent. net effect, with either of half a dozen of the best turbines, say the Geyelin, Hercules, Humphrey, Hunt, Leffel, Risdon, Swain or Victor, all of which have shown higher records than 80 per cent. With this effect you can get a horse-power *net* for each cubic foot of water per second on an 11-foot fall. Do not, however, as the writer has seen done, plant a mill requiring 300 H-P on a stream which would furnish only 100 H-P for 6 months in the year, and have to haul coal from the railroad 3 or more miles distant to supply steam for the balance.

So much for the cost of water power. For its value I return to the old rule. It is worth, in any place, if it should be needed at all, what it will cost to replace it by steam, and for this find the cost of coal per ton delivered at your boilers.

For triple compound engines allow 1.50 lbs. coal of best quality, per hour, per H-P, or, to be safe, say 1.75 lbs.; for double compound, 2 to 2½ lbs.; for single condensing 2½ to 3 lbs.; for high pressure, 3 to 3½ lbs., according to size of engine as shown above.

To the cost of fuel add wages of engineer and fireman, cost of oil, and 12½ per cent. on the cost of the plant, for sinking fund for renewal, interest, insurance and taxes, repairs and supplies, and you get pretty close to the cost of a horse-power of steam as representing the only known measure of the *value* of a horse-power of water.



MEANS FOR PREVENTING ELECTROLYSIS OF BURIED METAL PIPES.

By Isaiah H. Farnham.

LAST year there was read before the American Institute of Electrical Engineers in New York and Chicago a paper entitled "Destructive Effect of Electrical Currents on Subterranean Metal Pipes." So numerous and recent had been the examples of pipes destroyed by some "mysterious agent," sometimes attributed to the true cause, but more frequently to some new and unexplainable action, that the scientific public was quite ready for the facts and suggestions set forth in the paper, and, as a natural consequence, the latter was given a wide circulation in scientific and semi-scientific publications.

In order to make clear the connection between that paper and this, the conclusions reached in the former should be repeated here. They were :

1st. All single trolley railways, employing the rails as a portion of the circuit, cause electrolytic action and consequent corrosion of pipes in their immediate vicinity, unless special provision is made to prevent it.

2d. A fraction of a volt difference of potential between pipes and the damp earth surrounding them, is sufficient to induce the action.

3d. Bonding of rails, or providing a metallic return conductor, equal in sectional area and conductivity to the outgoing wires, is insufficient to wholly prevent damage to pipes.

4th. Insulating pipes sufficiently to prevent the trouble is impracticable.

5th. Breaking the metallic continuity of pipes at sufficiently frequent intervals is impracticable.

6th. It is advisable to connect the positive pole of the dynamo to the trolley lines.

7th. A large conductor, extending from the grounded side of the dynamo, entirely through the danger territory and connected at every few hundred feet to such pipes as are in danger, will usually ensure their protection.

8th. It is better to use a separate conductor for each set of pipes to be protected.

9th. Connection only at the power station, to water or gas pipes will not ensure their safety.

10th. Connection between the pipes and rail, or rail return wires, outside of the danger district, should be carefully avoided.

11th. Frequent voltage measurements between the pipes and earth should be obtained, and such changes in return conductors made, as the measurements indicate.

A great deal of discussion upon the general subject has since appeared in print. It is not the writer's object here to occupy space with a lengthy discussion of the facts and views of other writers, but rather to describe a new plan or method for minimizing the danger of electrolysis in cities and towns where single trolley electric railways are operated. Before doing so, however, it seems desirable to point out a few errors which appear to exist in the minds and writings of some, and which may tend to retard the efforts or impair the results of efforts put forth to prevent this new danger to so important a factor in municipalities as the water, gas and electric systems.

The error to which attention is first called is "that careful bonding of the rails will prove a sufficient remedy." The importance of good bonding is great ; but no amount of bonding will

wholly prevent a portion of the railway current from taking the earth and pipes buried therein, on its return to the station ; such current as reaches the pipes, small though it may be, will cause the action, unless means be taken to prevent its leaving the pipes for moist earth. The illustration on this page shows the danger of even small currents. It was reproduced from a photograph of underground telephone cables which were destroyed in Lowell,

WHAT ELECTROLYSIS WILL DO WITH TELEPHONE CABLE COVERINGS.

Mass., in the United States, within a few months, where the electric pressure between the pipe and surrounding earth was found to be less than ½ volt, indicating a comparatively small flow of current.

The second error lies in a proposed plan of joining the pipes to the rails at frequent intervals throughout a town. This has been thought to be a remedy. Such treatment would reduce the action upon the pipes in the district near the power station, but would increase it in other portions of the city. Such a system would prevent any passage of current from pipes to rails through the earth as a medium, but it would cause electric currents to leave the pipes for the earth in localities distant from the power house, returning to them again near the source of power, very much as the current now leaves and returns to the rails in railway systems of usual construction.

The third error is to be found in the assumption "that the danger exists only in large cities, or where the railway construction is unusually bad." The lower illustration on page 425 shows the destruction of an iron pipe which occurred in Rockland, a small city of the State of Maine, in the United States, where not more than six cars are ever in operation at one time. It should be remembered, also, that in the city of Boston, where damage to telephone cables has in the past years been considerable, the return conductors are comparatively large and well arranged. Besides the bonding of rails, a very large return wire follows back between the rails, this wire being in some streets ¾ inch in diameter ; in other streets it is composed of three or five ⅜ inch copper wires, placed side by side. Add to these conductors other

MAKING VOLTAGE MEASUREMENTS AT A CABLE SUBWAY MANHOLE.

heavy returns placed upon the poles and connecting with the rails at every ten poles or thereabouts, and the sum will indicate what care has been exercised to reinforce the conductivity of the rails. In fact, we are told the return copper in Boston amounts to 70 per cent. that of the outward conductors.

Notwithstanding such a system of rail and copper returns, a current of 500 ampères is taken from the lead sheath of telephone cables in the vicinity of the principal power house in that city,—good evidence, certainly, that good construction, as the term is ordinarily used, will not wholly retain the railway current upon the railway system of conductors.

Another error is the suggestion which has been advanced that "it is impossible to tell, with any degree of certainty, whether or not a seriously corroded pipe has been subjected to electrolytic action, or simply to chemical corrosion due to moisture, salts, acids, etc., found in the earth." This notion has, in some instances at least, led the officers of water companies and gas companies to the false conclusion that electric currents are "fickle," lawless manifestations, especially when encountered in the earth; therefore, it must be useless to search for electrolytic troubles or to attempt any remedy or prevention.

A pipe removed from the spot where it was corroded and presented to the electrician or chemist, with no further facts than its appearance, will, it must be granted, yield no certain or satisfactory proof of the cause which destroyed it; but, fortunately for practical purposes, we may with certainty determine whether or not such a pipe, when in its normal position and under its working conditions, is being electrolyzed, or even in danger of such action. The determination is made by taking voltage measurements between the pipe in question and the damp earth immediately surrounding it. Such measurements may be conducted with precision by any intelligent electrician, with the aid of a good voltmeter and two wooden rods, in the lower ends of which are

brads connecting with leading wires to the voltmeter. Where the pipes are found to be positive to the earth in which they rest, electric current will certainly flow from the pipes to the earth, and where the flow is in that direction, electrolysis is sure to result.

While it is true that the amount of current flowing is the measure of the rapidity of the action, and that the voltmeter measures the pressure, rather than the amount of current flowing, it is also a fact that the volt meter proves to be a better instrument than the ammeter for determining whether or not there

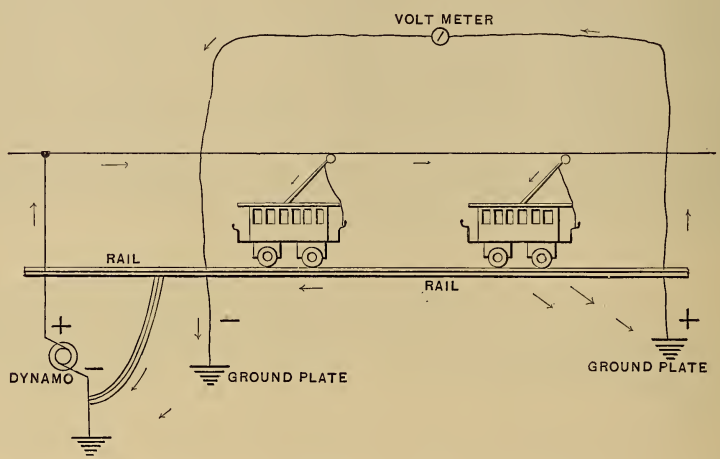


FIG. 1 —DIAGRAM SHOWING THE DIFFERENCE IN POTENTIAL ALONG AN ELECTRIC RAILWAY.

is a flow of current and in which direction it passes; and this knowledge it is important to procure in dealing with the question of prevention or remedy. The determination is easily within reach of all, and that, too, before the bursting of the pipes brings the matter to notice, too late for remedy. The illustration on the preceding page demonstrates the ease with which potential measurements are made upon electrical cables at manholes in the street.

Having referred to the method of preventing electrolysis, which has been employed on a portion of the pipes in Boston and in some other American cities for several years, and to some of the erroneous ideas on the subject, we may now present the outline for another method of minimizing the danger. No description of this plan has ever before appeared in print. It is furthermore attractive as lying entirely within the power of the railway companies to adopt. It is not excessively expensive and it does not involve connections with other companies' property, nor the mutual co-operation of cities or corporations. By this method the tracks of the railway will also be preserved from electrolytic action.

In order to bring the principle clearly before the reader, the writer would call attention to a fact generally known, but often ignored. In all cities where electric railways operating the single trolley system are in use, and especially where trouble from electrolysis has been discovered, it is found that the earth in one section of the city has a different electrical condition from that in certain other sections. If an insulated wire, having included in its length a suitable galvanometer or voltmeter, is extended between a ground plate located near the railway power house and another ground plate located a mile distant from the first plate, as shown in the diagram marked Fig. 1, a difference of potential will be found to exist between these plates. If the dynamo is connected with its positive pole to the trolley, the ground plate situated at the

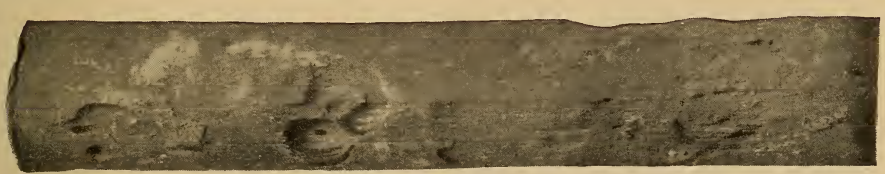
AN IRON WATER PIPE AFTER A FEW WEEKS' EXPOSURE TO ELECTRIC RAILWAY CURRENTS.

greater distance will be positive to the plate near the power house.

Some of the fire underwriters recognize this difference of potential as a danger and they attempt to rule against it. The writer has known such difference of potential to reach 50 volts and more. The earth in the distant territory is, so to speak, saturated with positive electricity, while near the station it is being "pumped out" or made negative by the dynamo. This want of a level, or balance, in the electrical condition of the earth, leads to a flow of the current from the higher to the lower electrical level, much as would occur if water should replace the electricity. In flowing, the electricity finds its way into pipes and cables, and, on leaving them at the lower level, causes the electrolytic action.

Fig. 2, on the next page, will, by analogy, fairly illustrate this want of electrical balance or level in the earth. The line A represents the surface of the earth; B, the surface of a flood of water produced by a heavy rain, and flowing to a low plane where a pump is drawing the water from the earth in a limited district.

If, now, we can preserve a level or balance in the electrical condition throughout the city, or, in other words, prevent a difference of potential, there will be no disposition for a current to flow from one portion of the city to another. It is the purpose in the plan now proposed to accomplish this equalization of potential as nearly as possible. To illustrate by the water analogy, Fig. 3 shows the flood of water being pumped from many points on the surface of the earth by pipes of proper size, so that there is substantially no difference of water level, and therefore no flow from one distant point on the earth to another. A comparison of this figure with the one above it will render the point clearer.



ANOTHER EXAMPLE OF ELECTROLYSIS.

As may be anticipated by a study of the principles already set forth, the new method consists in extending from the negative or rail side of the dynamo an insulated return wire, either on poles or underground, throughout the entire length of the railway, including all cross-town or branch tracks. This return wire is to be of such size as to properly carry the current and to maintain the return path at a comparatively low resistance. For a track extending three miles in any one direction from the power house a No. 0000 copper wire would give a resistance of but one ohm from the most distant point. Two such wires, about ⅓ inch in diameter each, would not seem excessive in cost, and would render the maximum resistance but ½ ohm from car to power house.

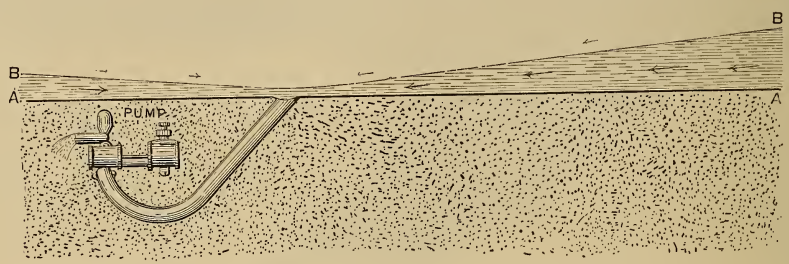


FIG. 2.—DIAGRAM ILLUSTRATING THE WANT OF ELECTRICAL BALANCE IN THE EARTH.

In large railway systems a still heavier main return may be employed. From this general return wire or system of wires frequent connections would be extended to the track system, say one at every other pole (200 ft.) Let these connections between the general return wire and the rails be of such size, or shape, as to cause the resistance from the rail at the nearest point to the power house to be the same, no more nor less, than from the most distant rail connection to the power house; that is, with such a system, if the resistance of the circuit from the rail, 3 miles distant, to the power house is ½ ohm, the resistance from any other point along the route of the track shall also be ½ ohm to the power house. Allow no ground connection on the dynamos, and no direct connection to the rails without the proper resistance. Fig. 4 roughly represents such a system. It should be understood that the rails are to be suitably bonded under this, as other systems using the rails for a portion of the electric circuit.

If, now, we imagine an approximately uniform distribution of cars, there can be no rise or fall of potential in the earth except at the very limited areas between the several points where the rails are connected to the general return wire system. Cars are not, of course, equally distributed over a city, and, therefore, perfect results cannot be reached by carrying out this plan, but to adopt it is certainly working in the right direction, and as the distribution of cars approximates uniformity, the advantages of the system will approach the maximum. On the other

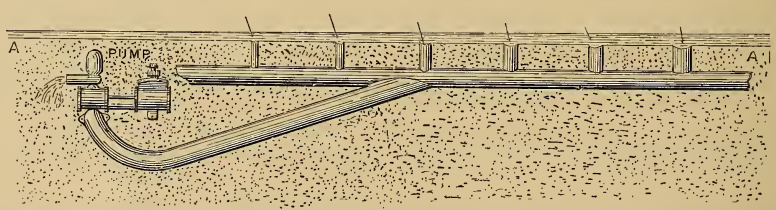


FIG. 3.—DIAGRAM ILLUSTRATING AN EXAMPLE OF ELECTRICAL BALANCE.

hand, with the present usual manner of connecting the return wires to the tracks there never can be a condition where a difference of potential will not exist between different sections of a city, no matter how nearly perfect the rail system is constructed as a return conductor, and, therefore, there can be no elimination of current passing from a higher to a lower potential throughout a city; and, of course, as the currents pass through the earth pipes are brought into the path, and constitute a portion of the electric conductor with all the possibilities of electrolysis wherever, from a poor joint or for other reasons, the currents leave the pipes for the damp earth on their way to the negative side of the dynamo.

This system of returning the railway current will accomplish several desirable ends :—1. It will allow but very little current to enter the earth and flow therein. 2. The current through the earth being minimized, electrolysis will to that extent be prevented. 3. Having by this means reduced the danger of electrolysis to small proportions, it will be comparatively easy to take care of the remaining danger, if such be found, by resorting to the means described in the previous paper. 4. In addition to practically overcoming the danger of electrolysis, the annoyance to telegraph, telephone, burglar alarm and other grounded circuits, due to difference of potential in different sections of a city will be incidentally removed.

The equi-potential return system just described has so far been tried in a New England city as to indicate practically that the benefits claimed for it may be confidently expected. There are no patents which will interfere, as the writer understands it, with the use of either system here referred to or described, for preventing electrolysis of underground pipes and other metal bodies. Railways, cities and corporations are at liberty to avail themselves of the results of many experiments, tests and practical experience briefly referred to here.

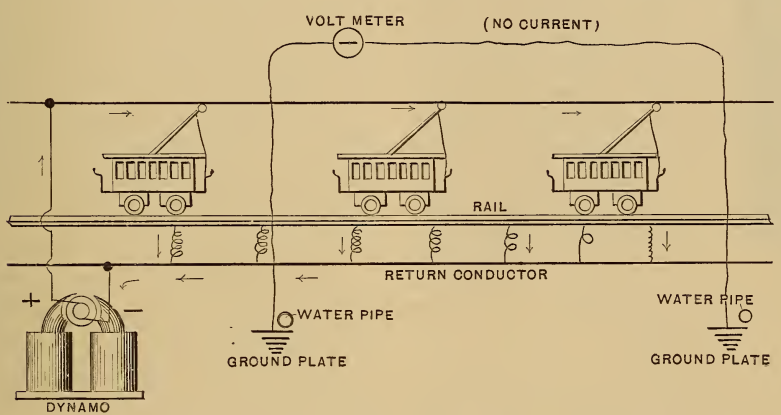


FIG. 4.—A SYSTEM WITH WHICH ELECTROLYSIS OF BURIED PIPES IS AVOIDED.

ENGINEERING FALLACIES.

By Henry Morton, Ph. D.

WHEN I wrote my first article on "Engineering Fallacies," which appeared in CASSIER'S MAGAZINE for January, 1895, I felt it necessary to apologize for drawing attention to so obvious a first principle as the doctrine of the conservation of energy and the corollary directly deducible from it as to the impossibility of perpetual motion in the sense of a self-moving machine, or one capable of doing work without a supply of energy.

Editorial articles, however, which have since appeared in the two most prominent engineering journals of England, demonstrate that no such apology was needed, but rather some explanation and argument by which the doctrine of conservation should be elucidated and its absolute certainty made clear, even to those who, I should have supposed, regarded it as axiomatic. Some of the questions thus raised I have discussed in an article in the April number of this magazine, but there are others of a more refined and metaphysical character, which have appeared since that article was published, and which I propose now to consider.

To begin with, it has been stated that in comparing our certainty of knowledge concerning the conservation of energy with our certainty concerning the relation of numbers of objects, I had gone too far, and that the latter was of a different order from the former, being the result of some sort of intuition and depending in no way upon experience, which was the sole foundation of the former. Now, while I freely admit that there is some difference, yet I maintain, first, that this difference still leaves the result of universal experience so reliable that there is no practical difference in the certainty of our convictions in either case, and that we are justified in acting on these convictions with equal promptitude and confidence ; and second, that such differences as does exist, is purely one of degree consequent upon our state of progressive development in matters intellectual as well as physical, and our increasing familiarity with the subjects.

My meaning in this connection will be best developed by a special instance. Galton in his "Tropical South Africa," cites the following experience with the Dammaras who appear to be representatives of the lowest stage of brain-development in members of the human race now existing :—

"When bartering is going on, each sheep must be paid for separately. Thus, suppose two sticks of tobacco to be the rate of exchange for one sheep, it would sorely puzzle a Dammara to take two sheep and give him four sticks. I have done so, and seen a man put two of the sticks apart, and take a sight over them at one of the sheep he was about to sell. Having satisfied himself that that one was honestly paid for, and finding to his surprise that exactly two sticks remained in hand to settle the account for the other sheep, he would be afflicted with doubts ; the transaction seemed to come out too "pat" to be correct, and he would refer back to the first couple of sticks ; and then his mind got hazy and confused, and wandered from one sheep to the other, and he broke off the transaction until two sticks were put into his hand and one sheep driven away, and then the

other two sticks were given him, and the second sheep was driven away."

Here we have a human mind to which the proposition that two objects added to two objects are the same thing as four objects is not obvious. And it certainly agrees with a very generally accepted theory of the development of mind to suppose that we owe our seemingly intuitive perception that two and two make four to our inherited as well as our personal experience in early life, and that we may reasonably hope that our descendants may one day acquire an equally intuitive perception as to the necessary truth of the conservation of energy and the consequent impossibility of perpetual motion.

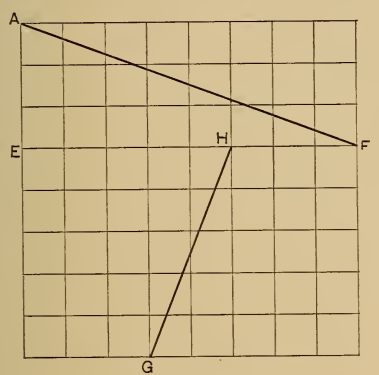


FIG. 1.

In one of the articles referred to it is also suggested that the idea that two objects added to two objects should produce five objects is inconceivable. As to this simple case, in the present state of our intellectual development, this is, no doubt, true. But let us try an example somewhat more complex.

Prepare, on a sheet of stiff paper, a drawing similar to the outline of a chess board, consisting of a large square divided into 64 equal small ones. Then divide this by cutting it in the directions indicated by the lines EF, AF, and GH in Fig. 1. Then re-arrange the pieces in the manner shown in Fig. 2. We shall then have a rectangle which will measure 13 small squares in one direction, and 5 in the other, or contain 5 rows of small squares of 13 each or 65 squares in place of the 64 squares which had existed when the same squares were arranged in 8 rows of 8 each. This ingenious puzzle appeared in a story entitled the Surdar's Chess-board which was published in *Harper's Monthly* during 1888.

At the first glance this certainly looks like an absolute demonstration that 64 objects may become 65 objects by a change in their arrangement. I think that it would be a very interesting thing to present this apparent demonstration to various minds as a test. I believe that in most cases those who believe in perpetual motion would accept it as conclusive and give up their intuitive certainty as to the unlimited scope of the doctrine illustrated by the expression that "two and two make four."

To those whose faith is supported by experience and has been so far developed as to make them incapable of believing in perpetual motion, it will only produce a sense of mental confusion until they have worked out the explanation of the puzzle, not only in its geometrical aspect which is reached when we observe that the "fit" along

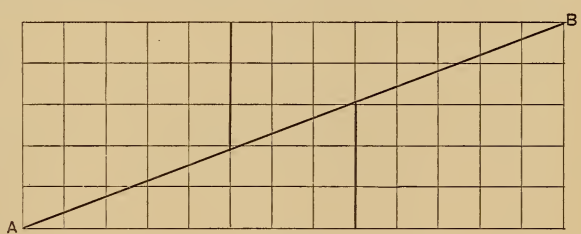


FIG. 2.

the line AB Fig. 2 is not accurate, but leaves a spindle-shaped area uncovered; but also in view of the fact that in Fig. 2, we can count 65 distinct squares, whereas there are but 64 in Fig. 1.

But this is not the end of this curious paradox. The four pieces may be arranged in the manner shown in Fig. 3, on the next page, with the result of reducing the total number of the small squares to 63.

This puzzle illustrates the fact that

combinations may be suggested which appear to violate the most fundamental doctrines and, yet, are not at once and instinctively appreciated as tricks or mere puzzles by all minds. There are, in fact, many statements which involve little more than numerical conceptions which, while demonstrably true, cannot readily, if they can at all, be grasped by the mind and fully realized.

Thus, for example, among the collection of microscopic objects in the United States Army Medical Museum, at Washington, is a specimen of microscopic writing on glass, which contains the Lord's prayer, written in characters so small that the entire 227 letters of that petition are engraved within an area measuring $\frac{1}{294}$ by $\frac{1}{441}$ of an inch. So far this statement does not trouble us. If, however, we go a little further we easily find that the area having the above dimensions would be only the $\frac{1}{129,654}$ of a square inch, and consequently that an inch square covered with writing of the same size, or counting 227 letters to each such fractions, would contain 29,431,458 letters.

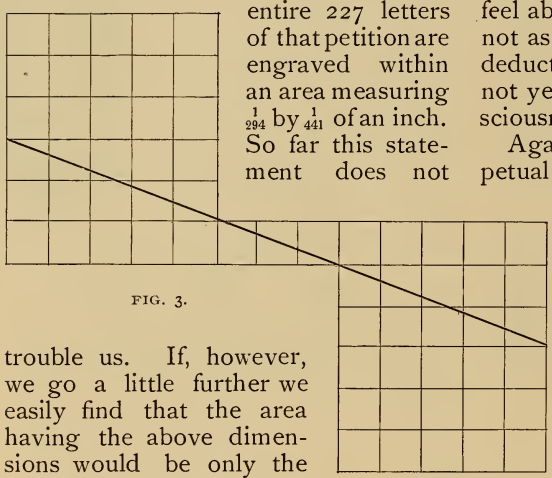


FIG. 3.

Let us put this figure into a concrete form by seeing how much of a book this number of letters would represent. The Bible is a book of which we may safely assume that every one has an approximate idea as regards its general size or extent. Some one has actually determined the number of letters contained in the entire Old and New Testaments, and finds this to be 3,566,480. Hence, the number of letters which a square inch of glass would accommodate, written out like the text of the Lord's prayer on this strip of glass, is more than eight times this last number, or in other words a square inch of glass would accommodate the entire text of the Bible eight times over written out as is the Lord's prayer on this strip of glass. I am free to confess that though this fact has been known to me since 1873, and I have had in my possession photographs taken with the microscope, of this writing, I cannot say that I fully apprehend or mentally grasp the fact just stated. I can form no mental picture of a square inch of glass with the entire text of eight Bibles engraved upon it, and yet, when I have verified the measurements and calculations leading up to this conclusion, I feel absolutely certain as to its truth, not as the result of intuition, but as a deduction from experience which has not yet developed into an intuitive consciousness.

Again, it has been stated that perpetual motion cannot be summarily rejected on general principles, or as axiomatically impossible, because Clerk Maxwell has suggested a possible case in which work could be accomplished without the expenditure of energy. This is his famous "Demon engine" problem. Though this may be familiar to most of my readers, I will, for the sake of clearness and certainty, briefly restate it, mainly in Maxwell's own words. It is premised that the various molecules of gas in a vessel are always moving with various velocities, some faster and some slower. Assuming this, Maxwell says :—

"Now, let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B and only the slower ones to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermo-dynamics."

This being the actual statement, does

it, after all, in any way support the idea of perpetual motion, or the doing of work without cost or loss of energy? Manifestly not. Admitting for the sake of argument that such a demon and valve, workable without work, are possible within the limits of a material as distinguished from a spiritual universe, there would be no work done in the ordinary sense, until the extra pressure, or the difference of pressure (due to temperature), on the two sides of the partition was used in giving motion to something. But the moment this was done, the extra heat would disappear in producing this motion and, taking account of the entire contents of the vessel, there would be a fall of temperature or disappearance of energy, corresponding to the work done. In other words, even if we admit that the demon-worked valve would defy the second law of thermodynamics, it would not escape the law of the conservation of energy, and we should only be filching energy from the air by reducing its temperature and applying the stolen heat energy to the performance of a corresponding amount of work.

It is true that in the article referred to, the suggestion is made that if the work developed as above was again converted into heat, the total heat energy of a finite material universe would be restored, but this is nothing more than a statement of the conservation of energy, or assertion that the total energy of the universe is unchangeable. It should be remembered that when we say that energy is expended in doing work, we do not mean that it is destroyed or taken out of the universe, but only that it is transformed. Thus, when a steam pump does work in raising water, it transforms only the kinetic energy of the steam into the potential energy of the lifted water ; and when a locomotive does work in hauling a train, it transforms the molecular energy of the steam into the mass energy of the moving train and the heat energy resulting from friction and the like.

It would appear, again, that the Demon engine, if made to do work, could do it only by the transformation of energy, like any common steam or air engine, its only transcendent property being the establishment of conditions admitting of the performance of work, by securing the violation of the second law of thermodynamics. This second law of thermodynamics can, however, I believe, be taken care of and protected, even from this Demon, by other arguments.

Thus, with all respect to the memory of Maxwell, I must say that I do not think this dream of his can be seriously considered as even unsettling faith in the second law of thermodynamics. This supposed demon by assumption transcends human intelligence in as much as he defies the universal laws of matter and mechanics in being able to open and shut a door without doing work, and in such a manner as to separate the almost infinitely numerous molecules of various, but always immense, velocities. Indeed, it would be no more of an assumption to suppose a check-valve operating without inertia or fraction, and adjusted to let the particles pass only in one direction. Then we should have a difference of pressure established on the two sides of the partition without reference to heat, and thus leave the second law of thermodynamics unrefuted, but by merely connecting the pressure side with an air engine and the other with the atmosphere, we could secure a motor which would derive its working energy from the atmosphere at large, and continue in motion until it had exhausted the molecular energy of the earth's atmospheric envelope. In this connection I would draw attention to a letter by Prof. J. Burkitt Webb, C. E., which appeared in *Engineering*, London, May —, 1895, and from which some of the above points are borrowed. It contains others of amusing and convincing character on the subject of Maxwell's Demon engine.

Surely such a "reductio ad absurdum" is enough to show that the demon and door, or automatic immaterial check-valves are not legitimate assumptions in the discussion of physical or mechanical problems, and, as I have

already shown, under no circumstances can we, even by these extravagant visions of super-material agencies, show a method by which work can be done for nothing or without a corresponding conversion of energy.

The editorial advocacy of perpetual motion as a legitimate subject for inventive skill and physical research, in *The Engineer*, to which I have before alluded, brings to my mind something similar which happened nearly twenty-five years ago and came within my own personal observation, and I believe that the story of what happened so long ago may be usefully related at this time in view of the fact that the notorious Keely is again before the public in some prominent daily papers and weekly journals, while several lesser lights are coming out in the perpetual-motion firmament.

In consideration of the feelings of many of those who are the descendants of the prominent men who were, in one way or another, connected with this matter, I will suppress names, but will say that every one to whom I refer was personally known to me at the time and that every incident I relate is veritable history.

Shortly before the summer of 1870, I was informed by a gentleman, intimately known to me, and who was at the head of one of the largest establishments for the manufacture of telegraphic apparatus of that day, that he had just heard of an invention in the way of an electro-magnetic engine which was soon to revolutionize the motive powers of the world. He described it to me as a machine operated by a few cells of ordinary galvanic battery, and developing a capacity for work equal to several horse-power, with a trifling consumption of zinc, say 3 ounces for 2½ horse-power continued for 9 hours.

I assured him that such a result was beyond the range of natural law and, in fact, a mechanical miracle, if it was not a mistake or fraud, and that the maximum capacity of zinc, assuming battery and engine both perfect in efficiency, was about one horse-power for one hour from each pound of zinc, so that the work stated, if performed by energy derived from zinc, would have required not 3 ounces, but about 22 pounds of zinc. These statements, however, had no effect. Mr. A—— had seen the machine in operation, had measured the power, and weighed the zincs of the battery before and after use, and was convinced. So also were many others whose names, if I gave them, would be recognized as those of some very well-known people, and among them were included two at least who have been largely connected with the development and practical application of the electric telegraph. In this goodly company was also included the editor of one of the two electrical journals then published in New York. I will allow him to speak for himself and describe what he saw and how his faith was established:

"A few days ago we accompanied, on invitation, several gentlemen to the works of Mr. X, of Newark, N. J. On a small shelf we found a Daniell battery of four cells, the ingredients of which were the bi-chromate of potash in the porous cell, and the dilute sulphuric acid, of ordinary strength, in the outer vessel. It was entirely inodorous. Beneath it, firmly bolted to the floor, was an iron circular frame of a diameter of about eighteen inches, the width of the periphery of rim being about five inches. Five apertures, equi-distant, were cut into the edge or face of this iron case, three and a half inches in length and of the width of the frame. Into these were inserted the faces of five iron cores, coiled with what seemed to us No. 14 covered copper wire, standing out from the frame and firmly fastened thereto. In the interior was a wheel, on whose rim were set six additional magnets, the same as on the iron case, and so set that the faces of the magnets in their revolutions would meet each other at different, yet regular, periods, corresponding with the double crank device in locomotives, to prevent a dead centre. By acting on the periphery, all waste of power was, of course, avoided.

"On the shaft which extended from

the magnet wheel, there was placed a belt wheel of the usual diameter, connecting with a wheel shaft on the ceiling, which, in its turn, was connected by a belt, with a circular saw on a bench. No power was gained by the diameter of the wheels, as they were all equivalents of each other. The wires were then connected, when, on the instant, great rapidity of motion was at once acquired, the floor of the room shaking violently with the power developed. Pieces of wood were sawn rapidly, and without apparently disturbing the rapidity or evenness of the motion. Two gentlemen, weighing 170 pounds each, endeavored to stop the motion of the wheel by the pressure of a concave brake, having a surface six inches by four, bearing on the belt-wheel, but without visible effect. This rapid and effective action has been watched nine consecutive hours by investigating parties, without any perceptible decline of power, and with a consumption of less than half a pound of zinc,—a cost of less than half a cent per hour. The power developed was rated at two-horse, and can be maintained for twenty-four hours without intermission, at a maximum cost of ten cents. Such at least is the statement made to us by Mr. X, and confirmed by a well known gentleman who thoroughly examined it."*

As might be expected, the above and its context of endorsement and enthusiastic prediction was received and commented upon with some disapproval in other journals ; so, in his issue weeks later, the editor of the *Journal of the Telegraph* writes as follows :—

"The smile which we anticipated on writing our recent article on 'Magnetic Motive Power,' rippled, as we supposed it would, into its peculiar curvatures of incredulity and scorn. We can have no objection to what we so plainly foresaw. We even congratulate ourselves in thus entering the list of simple and credulous men who have in all the time, earned a similar honour.

* * * *

"Yet we desire to re-affirm the fact to which we, in our last issue, with some superfluous enthusiasm, perhaps, referred, and of which, since then, we have received new corroboration. We have, first, the data of an examination by an experienced engineer, who gives the result of his examination as follows :

Number of cells of battery	4
Number of revolutions per minute	340
Diameter of pulley	12 inches
Pressure of brake	65 lbs.
Developed in horse power	1.99 to 2

"We also witnessed the only test lacking to us in writing our former article. It had been claimed that the work done by the saw of the motor was accomplished by acquired momentum. To be sure, we knew that momentum was a product and proof of power. But we wanted the test of initial motion against positive resistance. So a brake was applied by a man of good average strength, using all his force against a band wheel almost the diameter of that of the motor. The wires were then attached to a battery of three cups, and momentum was at once acquired in spite of the brake, and as if no pressure had been applied. This was done in the presence of gentlemen whom no charlatan could deceive. It was simply wonderful."

Again in his issue of March 15th, in reply to his critics, the editor says : "We stated what we saw and gave results which can be sworn to." And again, "but we claim a pair of good Scotch eyes, and are willing to be laughed at." In the same issue this editor reproduces an article from a religious journal of high standing, the *Christian Union*, which supports his views as follows :

"If the X motor does not prove the most extraordinary of the age it will certainly have to be named the most extraordinary fraud. From the knowledge we have on the subject there would seem to be no middle ground. The machine has certainly performed continuously with three-horse power, driven apparently by a two-cell battery at an insignificant expenditure of zinc. Expert witnesses testify to this. Three horse-power is not so small a matter

*The *Journal of the Telegraph*. Feb. 1st, 1871.

that it could be so easily obtained by some concealed motor, eluding the search of intelligent eyes. There has been a suspicious delay in making application to actual work of this wonderful discovery, as there has been abundant time since the first machine was put up, to multiply copies and set them to practical duty. It is only fair, however, to give them time for the elaboration of improvements.

"It is, undoubtedly, true that a number of prominent capitalists and electricians are sufficiently satisfied with the prospects of success to be Mr. X's backers, and we are told that a few weeks will settle the question. The *Scientific American*, representing orthodoxy on the subject, is very decided, not to say curt, in the matter. Orthodoxy is generally right, and adventurers who proclaim revolutionary discoveries before these discoveries are made good in actual practice, are generally wrong, almost always foolish, but in rare instances victorious. The *Scientific American*, in common with most of the regular authorities in mechanics, is quite beside itself on any hint of perpetual motion, and when Mr. X very foolishly proclaims that he can realize 2000 horse-power from three grains of zinc, it is like flinging a red cloth before a bull.

"Any one is safer in being skeptical on hearing such bluster as that. Nevertheless, a candid person must admit that this ghost of perpetual motion which is invoked so frequently to frighten inquirers is a nuisance, and tends to repress the investigation of truth. The men who use it have no clear idea of what they mean. Perpetual motion in the universe is a fact. In terrestrial mechanics it is, under present reasonings, an impossibility on account of gravitation. And yet we know too little about the forces that play around us to aver that none of them can ever be harnessed to our machines in such a way as to produce what would, in our present state of knowledge, be called perpetual motion. The science of mechanics is about the most complete of all, and from the nature of the subject the one most susceptible of the clearest determinations; and yet, even in this sphere, the most completely within our mind's grasp, there are a multitude of questions which a layman may ask that an expert can answer."

Some months after this, a visit was made to the motor of Mr. X by a young man then recently graduated from an engineering school, but who has since become one of the prominent physicists of the world, *i. e.*, Henry A. Rowland, now of the Johns Hopkins University at Baltimore. His eyes were not limited in their range of observation to the things he was *asked* to observe, and, as a result, he was able to trace the hidden force underlying the obvious phenomena in this case as he has since done with such success in the more difficult and satisfactory investigation of natural phenomena. His letter to the *Scientific American*, describing this visit, I here quote in full, only premising that the conditions described by him were exactly those which were observed by the present writer during a visit to the same place paid a few months earlier. Prof. Rowland's letter in the *Scientific American* of 1871, is as follows:—

"Having noticed several articles in your paper with reference to X's electro-magnetic machine, I believe I cannot do better than describe a visit which I paid it about three months ago. Entering the office in company with a friend, at about twelve o'clock one day, I was told that the machine was not running then, but would be in operation at one. Proceeding there alone at about that time, I was, after the formality of sending up my name, conducted by a small boy, through numerous by-ways and passages, to the second story of a back building where I was met by the illustrious inventor and a few select friends. Mr. X began by showing the small model machines, which he set in motion by a battery of four cups, of about a gallon capacity each. These models revolved very well, but apparently with no power, for they could be stopped easily. I then

began to reason with him on the absurdity of his position, and adduced in my support the experiments of Joule, Mayer, Faraday and others. He evidently had no very high opinion of these, and pronounced the conservation of force an old idea, which had been overthrown in these enlightened days by his experiments, though what the latter were I have never determined.

"After conversing some time to no purpose, he prepared to overthrow me and my authority at one blow, by an exhibition of the machine. This was standing in front of a chimney, on one side of the room, with the axis of its wheels parallel to the wall. The wheel to which the magnets were attached was, unlike the models, enclosed in a cast iron case, which enveloped it closely above, but spread out into a rectangular base below. The latter rested directly on the floor. The axis of the wheel projected on each side, and to one end a pulley was attached, and to the other the brake for operating the magnets. The machine had the general appearance of a fan blower with an enlarged pulley. The battery was attached to two binding screws, fixed to a standard on the chimney, and the current was supposed to pass from these along wires to the break piece and thence to the magnets. A belt on the pulley connected with a shaft overhead, whence another belt proceeded to the pulley of a small circular saw.

"As soon as the connection was made with the battery the whole apparatus began to move, and soon the saw attained great velocity, shaking the building with violence. The latter, in effect, was caused by a heavy fly wheel on the saw arbor, which probably was not well balanced. When well in motion boards were applied and sawed with the greatest ease. To show the excess of power they were sometimes placed on the edge and passed over the saw so as to wholly envelop it, and the cut made from end to end without the velocity being at all diminished. On throwing off the belt from the saw the machine still proceeded at the same velocity with entire indifference to external resistance. On mentioning this to Mr. X he informed me that when the saw was attached, and the resistance greater, the increased pull on the magnets brought them nearer together by bending the heavy iron frame; and, as magnetic attraction varies inversely as the square of the distance, it only required a small change of distance to account for the increased power. I clearly indicated that I was skeptical on this point, and suggested that it would also work without variation if the power proceeded from some well-governed steam engine in the neighborhood. Of this he intimated that if I were not careful a force might proceed from his body which would act in conjunction with gravitation in causing me to be projected through the window, and strike with violence on the ground below. The exhibition being over, on going down stairs in company with the rest, I tried the door of the room below but found it locked and the windows covered with papers. I desired to get in, but was met with the assurance that the room was rented by a man who was then absent.

"This, I believe, is the last visit paid by an outsider to this wonderful invention. I have been there several times since, but there has been no admittance to me or to any one else. I have since been to the owner of the building and find that Mr. X rents the room to which I sought admittance and also rents power in that same room which is directly below that containing his machine. The engine from which the power comes generally stops work at 12 and starts again at 1, but sometimes works all day.

"My visits there have established the following facts: First: That my friend and I were denied admittance at 12 o'clock, but were invited to come at 1. Second: That the shaft in the room below does not revolve between the hours of twelve and one. Third: That the room containing power was rented by Mr. X, but that he kept it carefully locked, and misguided me as to the tenant. Fourth: That the

working parts are concealed in an unnecessarily strong case, well adapted to the concealment of another source of power. Fifth: That part of the apparatus is attached to the wall so that the machine must always occupy the same position on the floor. Sixth: That the models have not a power proportionate to their size. Seventh: That the machine runs at the same velocity, whether producing one horse-power, or a fraction of a horse-power, and this without a governor.

"These are the facts of the case. Where the power of the machine comes from I am unable to say. Is there some secret connection between this machine and the shaft below, and does the battery, when applied, connect the apparatus with a larger battery? I leave these questions to others, but, unless the reasoning and experiments of a host of our greatest men be false, and unless the greatest development of modern science be overthrown, this machine cannot but derive its power from some extraneous source.

"In a late communication to your paper Mr. X sets himself up as the peer of Faraday, Tyndall and others, and gives as the reason his long devotion to science. He evidently does not consider that to be ranked with such men requires something more than devotion, it requires brains; brains to discriminate between true science and quackish nonsense; brains to discover and originate. And pray what fact, among the thousands of science, does Mr. X pretend to have proved beyond doubt? Let him answer. As to Mr. X's science, I assert that it is a tissue of error and ignorance from beginning to end. Even his vaunted invention of metallic foil, wherewith to envelop his magnets or wire, can operate in no other manner than to the detriment of his machine, as any such metallic coating lengthens and demagnetizes, which is the very thing to be guarded against. This is due to induced current, which forms in the coating, and, being in the same direction as the primary current, operates in the same manner to keep up the magnetism.

"His reason for the machine's keeping at the same velocity also shows great ignorance of the subject. In the first place, the law of magnetic force, under these circumstances, is stated entirely wrong. For this case the true law is complex, but most nearly approaches to that of inversely as the distance, instead of as the square of the distance. (See Joule and also Tyndall in the *London, Edinburgh and Dublin Philosophical Magazine* for 1850). And, in the second place, approach of the poles would not necessarily increase the efficiency.

"In this kind of machine there is a distance of maximum efficiency; and if the magnets revolve at a distance greater than this the attraction becomes too small, and if at a less distance, the times of magnetizing and demagnetizing the magnets become too great and the machine goes too slowly. The distance in this machine is, undoubtedly, within the limit, for Mr. X prides himself upon its smallness and so, further reduction, could it take place, can act in no other manner than the opposite of that claimed. But it is my opinion that all the force brought to bear on the magnets could not move them one two-hundredth of an inch when attached to such a frame.

"As to Mr. X's disregard for the conservation of force, I have little to say. His assertions are made directly in the face of this principle, and yet he has never adduced one experiment, or even plausible reason, to prove what he says. He takes you into a building where shafts are revolving by the vulgar power of steam, and directs you to look while he evokes power from nothing. You must not touch anything; you must not enter the room below; you must not be there when the engine next door is at rest; but you must simply look and by that renowned maxim of fools that 'seeing is believing,' you must believe that the whole structure of science has fallen, and that above its ruins, nothing remains but Mr. X and his wonderful electro-magnetic machine."

We might have supposed that this

letter of Prof. Rowland would have shaken the faith of even so firm an advocate as the editor of the *Journal of the Telegraph*, but it did not. In his issue of September 15, 1871, after alluding to this letter and other communications, he says:—

"These gentlemen indicate the suspicion that steam has more to do with the motor than the electric battery. To this point we address ourselves for a single moment. What we have before stated was based on what we actually saw and nothing more. All who have been favoured with a sight have seen the engine just as we did, and no one has yet underrated the power exhibited, or disproved the correctness of our statement of facts. The only diffference between us is that we believe and state what we saw, while the others suspect a concealed power."

While this was going on my friend Mr. A and those associated with him, being a little shaken in their faith, had made it a condition with the inventor that further supplies of cash should be withheld until one of his machines had been built in Mr. A's shops. This machine I saw in progress several times, and at last in operation when, with the same amount of battery as was exhibited in Newark, it developed an amount of power easily overcome by the application of a finger to the fly wheel.

Mr. X's plans and directions had been accurately followed and when he was asked to explain the failure, he practically admitted the fraudulent nature of his whole business by saying that he had never intended to carry out his agreement, but had intentionally furnished Mr. A with incomplete designs and instructions. This at last opened the eyes of Mr. A and his associates and, soon after, it was rumoured that Mr. X and his great motor had moved away.

The full account of this flitting and of the tracks left by the departed is well given in an article which appeared in the *Telegrapher* of April 27, 1872, which I quote in full:—

The Great Secret of the X Electro-Motor.

AN INGENIOUS FRAUD.

"Few of our readers, we fancy, have forgotten the excitement that was created in electrical circles last summer by the remarkable invention of Mr. X, who professed to have discovered nothing less than the long-sought-for perpetual motion, in the shape of an electro-magnetic engine which actually evolved power from nothing! Mr. X's claims were not only endorsed by a number of semi-scientific capitalists, who had faith enough to put up money on it, but at least one newspaper editor enthusiastically recorded his conviction that a great and most important advance in electrical knowledge had been made, and one which negatived the results of all previous experiments and experience with electricity and magnetism as a motive power, and prophesied an impending revolution in mechanics which would astonish the world and confound the teachings of Joule, Tyndall, Faraday and Farmer and other adherents of the doctrine of the correlation of forces.

"We were to see developed a power by the X electro-magnetic engine which could drive the Great Eastern across the Atlantic at the rate of 150 miles per hour with a single cup of battery and so on *ad nauseam*. But in one of the laudatory articles the cat was unwittingly let out of the bag. It was explained that the battery used in the X motor in all probability served only as an initial force. We were very strongly inclined to believe in this theory ourselves and always had a sort of calm confidence that the lapse of time would vindicate its correctness.

"A lively discussion was carried on for some months in the columns of the *Scientific American* between Mr. X and a number of hard-headed unbelievers; but this finally died away and he was left in peace to go on and complete his sixty horse-power engine, which, we were informed, was already on the stocks.

"Several months passed and we

heard nothing more of the wonderful invention till at length a disagreeable rumour reached us that Mr. X had left for parts unknown and that the celebrated electro-motor had been transformed into old junk. We thereupon concluded to despatch a trustworthy reporter to see how Mr. X was getting along. Our representative accordingly proceeded to the establishment in Bank street, Newark, N. J., where the elephant was formerly exhibited to admiring audiences. A well appearing boy, twelve or fourteen years of age, was the only person visible about the premises. The motor had disappeared and nothing remained except a few scraps of old machinery, metal, etc. Our representative interviewed the youth, with the following result:

Reporter: Can I see Mr. X?

Boy: No, sir, he isn't here now.

Reporter: When will he probably be here?

Boy: Don't know.

Reporter: How long since he was here?

Boy: Oh, as much as three months. We have been expecting him back a long time.

Reporter: Where would a letter be likely to reach him?

Boy: You might send it care of his brother in Boston, No. — Blank street.

Reporter: Could I see Mr. X by going to his brother's place in Boston?

Boy: Oh, no, he isn't there. I guess he is in Portland.

Reporter: I understand the electro-motor has been sent to a junk shop to be sold?

Boy (assuming a very childlike and bland expression): Oh, no, indeed, only some old scraps of brass and one thing and another.

Reporter: Would you allow me to look at the machine?

Boy: There isn't any machine here now; it's gone.

Reporter: What has become of it?

Boy: It has been packed up and sent away. I guess it went to Portland.

"Our reporter was not entirely satisfied with the result of this interview. To use a vulgar, but expressive phrase, he smelled a large sized mouse. He subsequently proceeded to make a tour of inspection among the junk shops of Newark, and finally his perseverance was rewarded by discovering the object of his search, or at least a considerable portion of it, in a scrap heap at No. 17 Railroad avenue. This portion consisted principally of the heavy iron base or pedestal which supported the machine. A careful examination of the remains threw a flood of light on the manner in which the old thing worked.

"Two rectangular apertures extended through the base from top to bottom, so arranged as to allow of a belt being concealed therein which passed over a concealed pulley on the main shaft of the machine inside the case. This belt also passed around a pulley on a shaft near the ceiling of the room underneath the engine. This room was always kept locked. Mr. X said it was rented by parties unknown to him. The owner of the building said that X himself rented the room and *steam power* with it. The electro-magnet, concealed wires being led down from the conductors, which apparently merely connected the battery with the commutator of the machine. This belt was left rather loose on the pulleys. The modus operandi was as follows: When the circuit was closed, the pulley beneath was thrown into gear by the initial force of the battery acting on the electro-magnet, but the belt, being quite loose, and the revolving portion of the machine being provided with a heavy pulley acting as a balance wheel, it would start very slowly, but in a short time would attain considerable velocity and power.

"Those who were fortunate enough to see the machine in operation will remember that although it weighed, including the base, perhaps 1200 lbs., yet Mr. X found it necessary to bolt it to the floor with four bolts. This would, however, have a tendency to prevent impertinent investigators from moving the apparatus with a crowbar

or otherwise, and thus throwing the belt out of line.

"Among the other relics discovered by our reporter in his course of investigation was a machine belt with two fine copper wires sewed on the surface near each of its edges. This, doubtless, played some important part in the internal economy of the motor, possibly serving to convey the initial force to the electro-magnet of the pulley in the room below. The whole arrangement was simple, neat and effective, and reflects a great deal of credit upon its inventor, as far as his skill in mechanical legerdemain is concerned.

"There has been so much anxiety, especially among the subscribers to the capital stock of the X Electro-Motor Company, to ascertain the secret upon which the wonderful electro-motor was based, that we have no doubt they will be highly gratified and grateful to us for giving them the information so long, and heretofore vainly, desired. They can now realize how excellent an investment of their surplus capital they have made, and what an injured innocent is Mr. X, formerly of Worcester, Mass., later of Newark, N. J., and now of parts unknown. The sublime, but more than child-like, confidence of the contributors to Mr. X's ample funds must excite general admiration. They were not to be fooled out of a good thing by old fogy electricians and absurd natural and scientific laws.

"It is to be hoped that X has saved enough of the funds subscribed and paid for the motor stock to keep him in comfort for some time, as it will not be practicable for him to devise another so ingenious a fraud, or to secure the confidence of capitalists again for at least two or three years. The great difficulty in such operations is that an entire new set of contributors must be secured for each operation. Water, gas and electro-motors have probably used up the available stock for some time to come."

This was the end of this bubble, remarkable equally for its utter lack of rational foundation and its success in misleading men who, in their general business relations, and even, in some cases, in technical applications of electricity, occupied prominent places in the community and deservedly enjoyed the respect and confidence of their contemporaries.

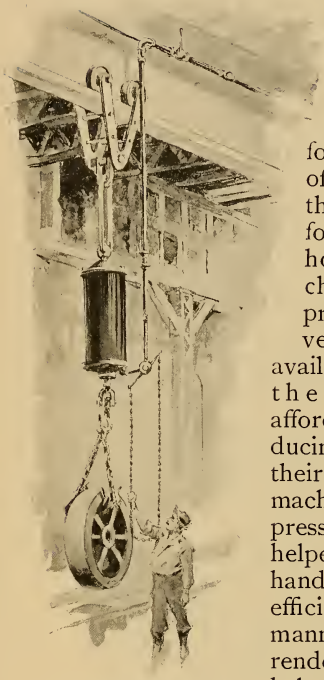
The above fragment of history has in it several valuable suggestions or lessons, one of which is that the engineer must carefully resist the argument frequently put forward in support of some fraud or fallacy of this nature, that there must be something in it because Mr. A, B or C, a prominent business man, or lawyer, or manufacturer has contributed to its financial support, or expresses his faith in its value. In such matters such authority should have no weight.

Again, the above emphasizes all that I have said about the importance of a firm faith, founded on understanding, in the conservation of energy. Those who entertained that faith were in nowise misled by deceptive appearances and specious assertions, but saved their money and their credit.

These lessons are none the less effectively taught if the names of those concerned are suppressed as above, provided we know that the individuals existed and said and did as reported, and as I should regret being the cause of discomfort of any sort to anyone even remotely concerned, I have substituted letters for names as above.

COMPRESSED AIR FOR ENGINEERING WORKSHOPS.

By C. O. Heggem.



A COMPRESSED AIR HOIST.

CONSIDERING how very convenient a medium compressed air is for the transmission of power to out-of-the-way places and for use in lifts and hoists about a machine shop, it is surprising to note how very few shops have availed themselves of the opportunity, afforded by it, of reducing the expenses of their plants. In the machine shop compressed air serves as a helper for the machine hand in a far more efficient and economical manner than that rendered by the manual help, which, in some shops, require a special order from the foreman, in which case the foreman must be hunted up and asked for a helper. If he be in good humour he may detail one at once; if not, he may tell you that you do not need one, or he may not answer you at all, and go on and forget all about it. In the latter event you will have to get some one as best you can.

In other shops, helpers are kept "loafing around," ready to be called by any in need of them. Under this arrangement if you "stand in" well they will notice your first signal, but if you are a new man, or worse yet, if you happen to be known as holding views concerning the amount of work a man should turn out in a day, which are at variance with the orthodox notion of that shop, you may call in vain one helper after another, and each one will promptly fail to notice you, and be very busy with something else just then. Finally, you get some one, but in the meantime, a great deal of time has been frittered away, and some bad feeling stirred up.

All this can be corrected and the time saved by putting in air lifts over all lathes above 20 inches swing, and over all planers, shapers, drilling machines, and drill presses working on pieces too heavy for one man to lift. These lifts are always ready,—the helper is right there,—and so quick and satisfactory are they in their action as to leave out of comparison all chain blocks, chain hoists or chain rigs of any kind. A very cheap form of air lift, shown in Fig. 1, is the plain cylinder, suspended from a trolley traveling on a swinging arm, the cylinder being about four feet long, and for all lathes below

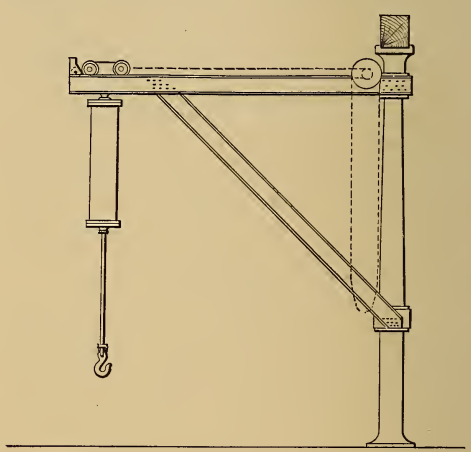


FIG. 1.—A CHEAP AIR HOIST.

36 inch swing, or planers 30 x 30 inches, it need not be more than 6 inches in diameter. Such hoists would lift about 2000 pounds with an air pressure of 80 pounds per square inch.

Chucks, face plates and steady rests can be lifted from the floor and placed in position by the aid of the compressed air hoist in less time than by hand, and work can be lifted and placed against the face plate or in the chuck with much more satisfaction, and in less time than by any manner of "blocking up" in vogue with the old helper system.

Very convenient little presses can be fixed up for driving mandrels, pressing in seats for valves, linings in piston rod glands, etc. The presses are made with a cylinder 16 inches in diameter, which, at 80 pounds pressure, is equal to about 16,000 pounds pressure on the ram. As shown in Fig. 2, the cylinder forms the base of the stand or press, and the different kinds of work are held down against the table by quickly removable clamps. To any one who has watched the waste of time and energy in the process of driving out a mandrel with a sledge hammer, the awkward "misses" of the novice, the battering and upsetting of the mandrel, the spoiling of the centre, the bruising and, perhaps, breaking of the work itself, as, for instance, arms in small pulleys, which are frequently jarred off in this manner, the compressed air press will at once commend itself as an addition to a well-equipped machine shop, worthy of the last decade of the 19th century.

In turning soft steel shafting, it is customary to use water to which a certain percentage of sal-soda has been added, in order that the water may not rust the finished work, and with a keen tool of the proper temper, and wide enough cutting edge to cover the feed, a very smooth and shining surface can be produced. But if the shaft is to be parallel for any great length, this method of finishing will not answer, because the tool will constantly be crowded away from the surface, and this will, of course, produce a tapering shaft. As the tool is being crowded away, it crowds more over the harder portion of the steel than the softer ones, and the result is, in addition to a tapering shaft, also one that is not round.

For this reason, a good lathe hand will run his finishing cut dry over journals, and places in the shaft that he is very particular about, but the dry finish is not so smooth, and requires

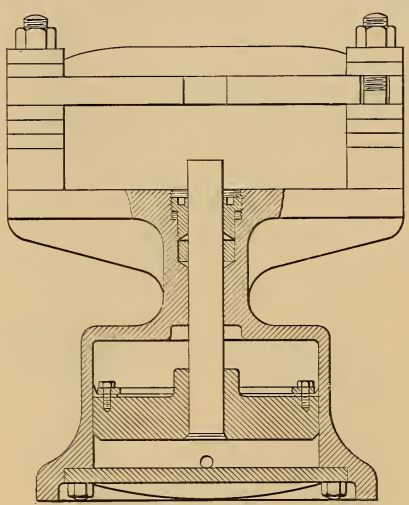


FIG. 2.—A COMPRESSED AIR PRESS.

considerable grinding, either by lead-lapping or any other process of grinding, to make it finished. By using a small air jet, that is, air issuing from an orifice of about $\frac{1}{16}$ inch in diameter, the work can be finished very much the same as if water is used. A smooth surface will be produced with this important difference, that the tool will not crowd, and, consequently, the shaft will be nearer true and straight when using a compressed air jet than when using water.

The same sized air jet may be used to advantage at different places around the shop. It is excellent for cleaning off benches and machines, and, is much to be preferred to the common dust brush used for this purpose. It is also very convenient at the drill press for blowing out the chips, in drilling and tapping bottom holes. Inventive genius, in fact, will find a wider field for the exercise of his ingenuity in the application of compressed air to the different

processes in vogue in a machine shop than in that of most other available forces.

On the erecting floors compressed air comes in for a good share of the work. Convenient cranes make it not only possible, but much more satisfactory for one man to erect an engine, for instance, than if there are two or

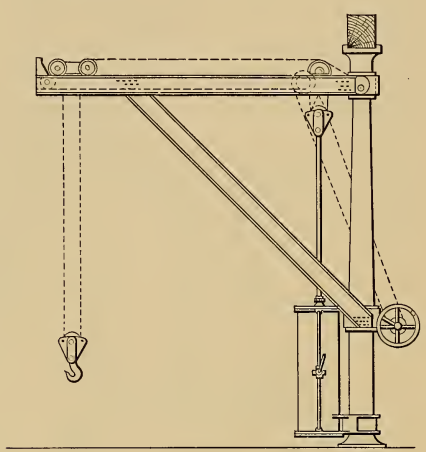


FIG. 3.—A COMPRESSED AIR CRANE.

more about it. The crane shown in Fig. 3, is mounted on one of the columns supporting the roof, and revolves on ball bearings entirely around the column. Its circle of operation is 20 feet, and its lifting capacity, five tons.

The sketch shows the construction so plainly as to render a description unnecessary. Any piece on an ordinary-sized engine can be picked up and put in position by one man just as readily as if there were two or more about it. In scraping the valve, for instance, the valve is lifted off its seat, after having been rubbed sufficiently to make its markings, and left suspended in the air while the seat is being scraped; then it is again let down for another rubbing, and so on until the job is completed.

Any one at all conversant with the work will readily appreciate what a convenient arrangement a crane of this kind can be made for this class of work. Here we come to the use of flexible shafts for drilling cylinders and drilling and tapping hubs of wheels, etc. A few years ago we used to consider that the flexible shaft was a very convenient thing for this purpose; and so it was, but its costs of maintenance, when used to produce work in large quantities, or, to be plain, when the use of the flexible shaft has changed from running it once or twice a day, at most, to constant and continual use, become considerable, and compressed air seems to come in as if made on purpose to fit the occasion.

Small engines can be run by air, and made to drive drills and taps and a variety of tools, far better and cheaper than by the use of the flexible shaft. There are other drills, made for the use of compressed air direct without the intervention of the flexible shaft, and these answer the purpose admirably, though the small engine plan has given the writer more satisfaction than the other.

Where electrical over-head cranes are used, the air jet will be found very handy for keeping the armatures and, in fact, the entire crane clean. The dust can be blown off more effectively, and hidden recesses can be better reached than by any manner of brushing or cleaning, no matter how carefully done.

When we reach the boiler shop, the compressed air field widens materially. Indeed, it seems as if the different processes had been adapted or made to

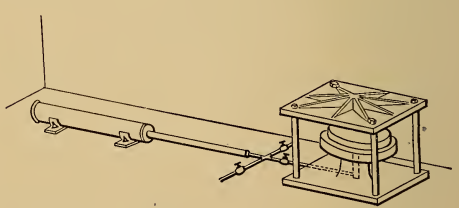


FIG. 4.—A COMPRESSED AIR FLANGING PRESS.

show the beauty of compressed air-driven machinery to the best advantage. —punching, shearing, flanging, riveting, caulking, flue-setting and beading. Each process can be better, neater and more economically accomplished by the use of compressed air than in the old

way. Punching may be done by having a small cylinder at the back end of the machine, attached to a lever or arm, suitably pivoted, at the other end of which the attachment is made to the head carrying the punch. Such an arrangement is especially well adapted for quick work required in the construction of smokestacks, breechings, tanks, and all work not requiring heavier than ⅛ inch or, say, No. 8 gauge of iron or steel. With these presses arranged so as to be operated by a foot-tripping device and equipped with jigs, it is surprising how much more work can be done than by any system of laying out.

The different processes of shearing can be similarly accomplished. For flanging, so long as it is confined to light work, used in the construction of tanks, or where the sheets are small and do not exceed $\frac{3}{16}$ inch in thickness, air pressure, applied directly under the ram carrying the die, is very satisfactory ; but when it comes to boiler heads, varying from $\frac{5}{16}$ to ⅝ inch in thickness, and of such a variety of forms as are required in the construction of locomotive boilers, it is better to apply the air pressure in a way somewhat similar to that in which the weight is applied to an accumulator.

A 16-inch diameter cylinder, Fig. 4, may be placed in any corner of the boiler shop, or may be laid down on the floor, along the wall, in order to be out of the way. To the piston is attached a plunger, 4 inches in diameter. This cylinder and plunger are made sufficiently long to enable the water that the plunger displaces to equal the displacement of the piston in the flange press, and this flange press may be located in any convenient place, and the water conveyed through hydraulic piping from the casing inclosing the plunger at the air cylinder. An air pressure of 80 pounds would here furnish an hydraulic pressure of 1286 pounds per square inch, which is sufficient for any ordinary boiler shop operation on the hydraulic plan, be it flanging, riveting or any other process. A small tank should be placed on this system ; or, better yet, it may be connected to the city or shop water works, and a check valve placed between the tank, or between the water main and the hydraulic apparatus, the object of this being to maintain the system completely filled at all times, and make up for all leakage.

A number of special tools have been on the market for some time, made for compressed air caulking. Some of these tools do the work very effectively, and with a minimum amount of discomfort to the man running it, in the shape of reduced jar, and to the balance of the boiler shop personæ in the shape of a little less noise, possibly, than some others, though any person who has spent ten minutes in a boiler shop operated by compressed air, where two

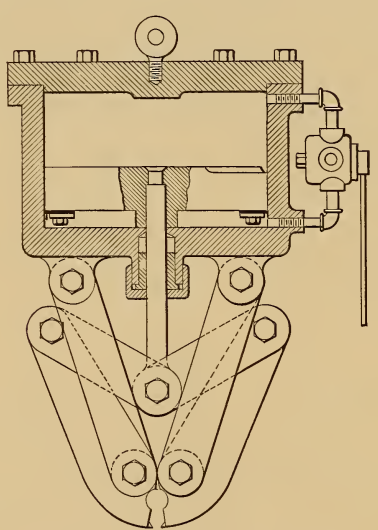


FIG. 5.—COMPRESSED AIR SHEARS.

or three 72-inch shells were being caulked by pneumatic tools, will probably never forget the din. But, as noise is inseparable from the boiler shop anyway, it need hardly be taken into consideration, and, in fact, it is like a good many other things,—we eventually become accustomed to it.

But it is an incontrovertible fact that caulking can be done better and cheaper, and that it is done very much cheaper by air pressure than by hand. To do good caulking, the air pressure should not be allowed to run down, and when

good work is mentioned in this article, it is always understood that 80 lbs. pressure of air is on "tap."

In beading flues, the edge should be laid well over with a hammer before commencing the beading process, though it is not necessary to take any more pains in laying it over than is ordinarily done when beaded by hand; but the pneumatic tool will make just as nice, and just as good a bead as was ever made by hand, and in less time.

Tapping for stay-bolts, driving the stay-bolts, and finally shearing off the stub end (see Figs. 5, 6 and 7) is not only done at less expense, but, like all machine work well done, excels hand work of the same kind. In convenient places small furnaces are erected for heating rivets, and these are supplied with their blast with the ever-present air, care being taken to have the orifice so small that it will not needlessly drain the air supply, and yet be large enough to blow the fire.

In our stroll through the establishment in search for further application of the air pressure, we reach the blacksmith shop, and there one would at first think that compressed air had no application; still, it is as well applied there as elsewhere. In that department, coupled with the knowledge of the nature of the material to be worked, that which determines, more than anything else, the success of the worker in iron or steel (whether he be engaged as the "village blacksmith" or "forging the anchor") is the trained and artistic eye, which, assisted by a constructive mind, has the object in perspective before the material is shaped to it, the latter process depending upon the skill of the artisan which, to be effective, must always go hand in hand with good judgment, thus meeting the ever-changing circumstances which forbid of rules. This leaning to the artistic, let it be natural talent or acquired, or both, measures the degree of finish, and grace of form that a piece will wear when it leaves the workman's hands.

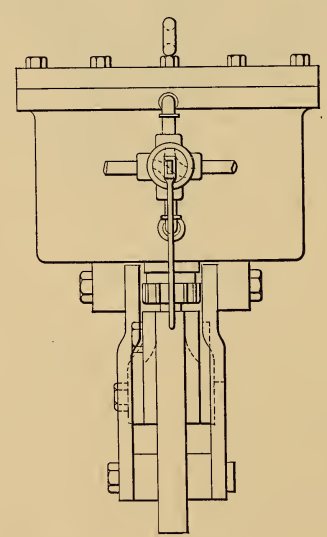


FIG. 6.—SIDE VIEW OF FIG. 5.

After this, the most important requisites are plenty of good, clean fuel and a strong steady blast. Nothing is more aggravating to an ambitious workman than to find the blast weakening just about the time when a heavy heat for "a good weld" is reaching the most delicate stage, so that he dare not leave it in the fire to waste, nor take it out, because it is not ready for the "knit." Again, when it is desired to heat iron or steel uniformly, it is just as trying to do it with an irregular blast.

With compressed air these difficulties are overcome at reduced expense against other methods, dispensing with all unsightly piping and reducing the cost of repairs to a minimum. The pipe is laid along the floor behind the forges, with connections to each fire, and with a pipe tapered to ¼ inch opening, a blast sufficient for the purest and most thoroughly "soaked" white heats in heavy weldings is produced.

With equally satisfactory results is the blast regulated for the several stages of forging, hardening and tempering, being always uniform. For handling heavy forgings, shafting and other heavy pieces, which often find their way into the blacksmith department, compressed air can be utilized with equal advantage to that mentioned in connection with the other departments.

With all furnaces adapted to the use

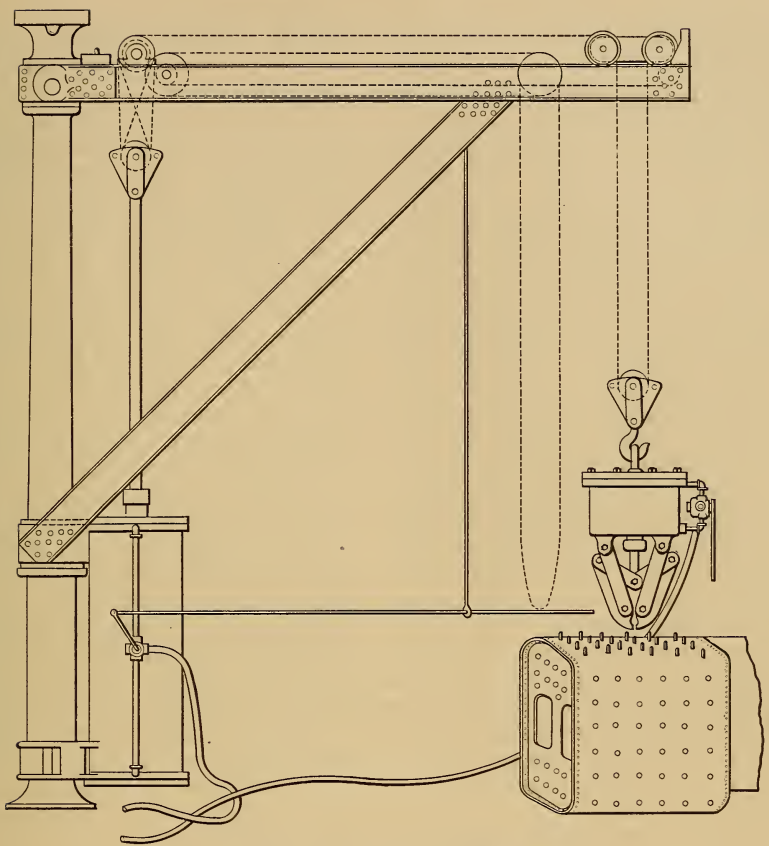


FIG. 7.—SHEARING STAY-BOLTS BY COMPRESSED AIR.

of liquid fuel, compressed air can be made to play a useful part, first, to bring the petroleum from the tank in the ground, and then to atomize it at the burner. The piping and valves in this connection should be so arranged that when the fire is put out, the blast shut off, as it were, the pressure will be relieved in the tank, so that the oil in the shop at the different burners will flow back into the tank. By this arrangement a great deal more neatness is obtained than by the abominable custom of placing a barrel behind, and somewhat above, the tuyers, this barrel becoming filled, and sometimes running over, with crude petroleum, and usually emitting an odour anything but agreeable.

In a blacksmith shop where a number of forges are equipped in this manner, grease seems to cover everything, and there is a stickiness about the department that is extremely disagreeable. Even the floor becomes slippery with grease, and it is to be supposed that the insurance companies make vigorous protests against these conditions. With the tanks in the ground, with the compressed air system in use, as already outlined, everything changes, and there is no more evidence of oil being in use than if the furnaces were kept going with coke. Trip hammers and drops are operated by this same pressure, and, in fact, such things as line shafting and belting in the blacksmith shop are entirely eliminated.

Having reached the foundry, we hear the blasts of escaping air on all sides. Here are direct lifts or suspended cylinders of five tons capacity, cranes in

which the cylinders are laid in the floor and operated through wire cables; but each kind acts with that nimble, elastic softness that is so essential to successful work in the foundry. Copes are lifted off without any jar, no chain links to climb and slip, which little occurrence has shaken out many a cope. Patterns are lifted out just as slowly as you please, until they are clear of the mould, when you may lift them just as fast as you please. Large green cores are placed in position to dry without any jar or shock of any kind. All this softness and elastic action of compressed air for lifting purposes in the foundry will commend itself to any practical foundryman without using any argument whatever in its favour. Here the air jet is made to take the place of hand bellows for blowing out the mould, and it takes the place of the dust brush for cleaning patterns. It is used as an atomizer of petroleum for burning or skin-drying large moulds, and in this application it so far outstrips, in point of economy and effectual work, anything that has been accomplished by the old method of burning charcoal in iron baskets, as to leave no room for comparison.

A very convenient little apparatus for testing the shrinkage, deflection and breaking strength of foundry test bars has been in use for the past three or four years. It consists essentially of a 6-inch cylinder, placed on end so as to bring the piston rod against the centre of a horizontally supported test bar. The back of the instrument supports three dials, or gauges, upon which the readings of deflection, shrinkage and breaking strain are given. The whole apparatus occupies a space of only 28x10 inches. Some experimenting has been done with a view to determine how far it would be practicable and economical to substitute compressed air for the wind-blast in melting iron in the cupola, but so far the effort has not been as successful as desired. The case, however, is not hopeless, and future experiments may develop something that is desirable.

Coming from the foundry to the cleaning room, we find compressed air used in cleaning castings, not only operating as a sand blast, but made to rotate wire brushes, held firmly with both hands, and small emery wheels. There is no doubt that compressed air can be brought into more general use in the cleaning room than it is at present. Cast gearing, for instance, can be more cheaply cleaned by the use of emery wheels operated by compressed air, than by the old process of hand cleaning, and a variety of castings, now requiring expensive hand labour, can be cleaned better and cheaper by some kind of air process. The casting cleaning room, perhaps owing to its generally dusty and uninviting condition, has not received the attention from compressed air that it, perhaps, demands.

Another application of compressed air is the handling or conveying of the different kinds of oil used about any establishment. Tanks for engine oil, lard oil, cylinder oil and lubricating oil are buried in the ground, convenient to the track where the oil is unloaded by running it into these tanks. The oil is forced to wherever it may be wanted, and compressed air delivers it there. By having the lubricating oil and the lard oil faucets in the tool room, each workman is supplied with his oil just as he is with any other tool, subject to an order from his foreman, and the splash and waste of high-priced lard oil is reduced to a minimum.

Did the reader ever have to fill his oil can from a barrel of lard oil in the winter time, in a room with a temperature somewhere between the freezing point and zero? This operation always suggests the picture of a barrel with one head broken in, and a splinter of wood as a spoon, used for conveying the stiff lard oil into an oil can through an orifice about ¼ inch in diameter. Usually, while a small chunk goes into the oil can, a large one drops on the floor, and the smear and waste is enormous. The compressed air arrangement not only abolishes this waste, but, by reason of the tank being buried in the ground below frost, the lard oil is kept liquid at all times. Moreover, this

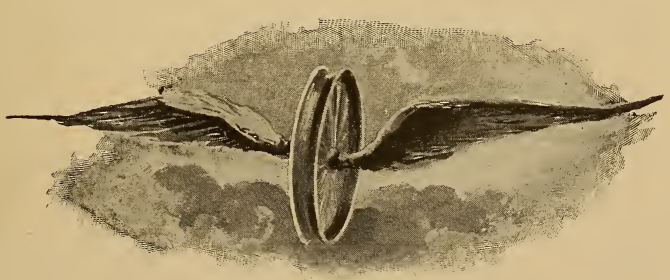
arrangement has the additional advantage of reducing the fire risk, and thereby lessening insurance rates, besides adding to the general neatness and systematic working of the establishment in no small manner.

The sprinkling pipe system for fire protection is rendered safe against frost by filling the pipes with compressed air during the cold months of the year. And we might go on multiplying instances to show the application of this convenient medium; but fear of becoming tiresome suggests concluding this article. Before doing so, however, it may, perhaps, be well to call attention to a few points that the thorough, though, at times, expensive teacher, experience, has prompted. Put in a compressor, two or three times as large as you think you will actually need,—and a belted compressor is to be preferred to a steam-driven one where the main engine running the shop machinery is sufficiently large to carry this addition. It is preferable, because it is more economically run, no matter from what standpoint the economy is viewed.

A reservoir or storage tank should be placed in proximity to where the greatest amount of air is being used, and if, as in large plants, the foundry, machine shops and boiler shops are widely separated, it is well to have a reservoir at each of these places. Considerable water will accumulate in these reservoirs, and means should always be provided for drawing it off. This should be regularly attended to at least once a day.

The pipes should be laid fully as deep as water pipes, say four feet below the surface, and should be laid, also, with a view to perfect drainage. It is very essential for the successful working of the plant that the matter of drainage be systematically attended to. An automatic device for stopping and starting the compressor when the desired pressure is reached is much more economical and desirable than the use of a pop valve to relieve the pressure. The former is economical; the latter is wasteful.

Careful attention to these points may save a great deal of trouble, especially during cold weather. An experience of five or six hundred feet of compressed air pipe frozen up, with the foundry crippled as a result, with fire kept burning on the ground the entire distance for fifteen hours, during which time a temporary pipe was run over head, made an impression on the writer not soon to be forgotten, and attention is called to it solely for the purpose of saving others the same trouble.



A CONVEYOR IN OPERATION. CROSSING A LEVEE.

CABLEWAYS FOR UNLOADING VESSELS.

By William Hewitt.

THE economical handling and distribution of coal is something that has a vital interest to all, and one of the most important problems in connection with this, perhaps, is the loading and unloading of vessels. The object of this article is to describe a couple of cableways for this purpose that possess some novel features.

The first one to be considered was designed especially for stocking coal yards from masted vessels at a dock. Two patent, locked-wire cables, 1⅛-inch in diameter, are stretched between the two terminal structures and over intermediate supports, about 100 feet apart, and constitute the main trackway over which a hoist carriage travels. The terminal structure and supports may be mounted on wheels that traverse surface rails, or they may be permanent affairs as desired.

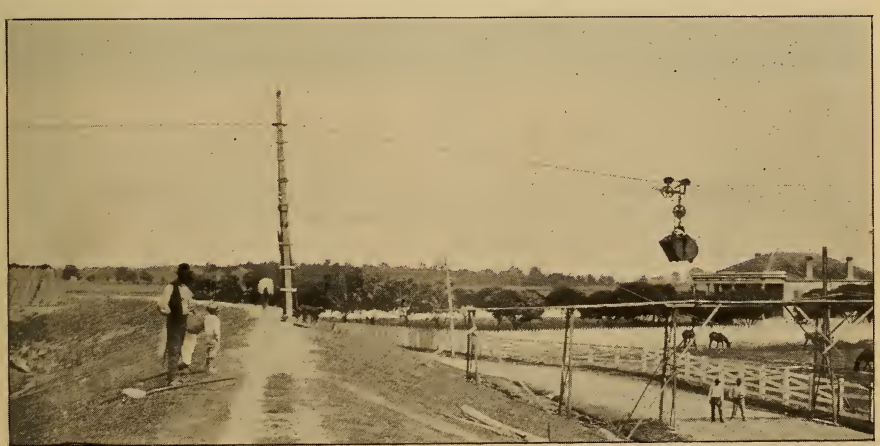
For the information of those who are unfamiliar with the construction of the patent locked-wire rope referred to, the writer should state that the outer wires of this rope are drawn to such a shape that, when they are laid up, one wire interlocks with the next, making a rope with a perfectly smooth surface, and, at the same time, possessing the flexibility of an ordinary rope of the same strength. The merits of this rope are now pretty well understood, and as a trackway for a traveling carriage it is far superior to the ordinary wire rope. It not only

lasts much longer, owing to the greater wearing surface exposed, but the smoothness of this surface also adds greatly to the life of the carriage wheels that run upon it. It requires less material to cover it, and, when so covered, is impervious to water and, consequently, less subject to internal corrosion, which is a great advantage in a rope that must be constantly exposed to the weather.

The cables are anchored securely at the dock terminal, and at the yard terminal they are wound on drums operated by a ratchet and lever, the latter being provided in order to let out the cables and thus release them of the heavy working tension to which they are subjected when shifting from one position to another. If the line be a fixture these drums may be replaced by counterweights.

The yard terminal structure supports the engine and boiler that operates the line, the engine being one of special design made expressly for operating cableways of this kind, in which the hoist carriage is moved by a light, endless rope, or, rather, one joined by connections on the carriage, and in which the hoisting is done by an independent rope, rove about sheaves in the carriage and a fall block below the same, to which is hung the bucket or receptacle for holding the coal or other material, as the case may be. In the special application under consideration self-dumping buckets are used, of the ordinary type, such as used in derrick work. There are two buckets in an outfit, each capable of holding a ton of coal, one being loaded while the other is taken over to the yard and back. The engine has double cylinders, 8¼ inches in diameter by 10 inches stroke, and is provided with two drums, one being grooved in the usual way for operating the hoisting rope, and the other for operating the hauling rope, having an oval-grooved rim about which the rope is simply lapped two or three times. Both drums are on one shaft and are driven independently of each other through friction connections. The boom at the dock terminal is hinged in such a way that it can be raised by a winch, provided for the purpose, in order to clear the rigging of the vessels while these are coming alongside the dock or departing.

The other cableway referred to is one designed for stocking the sugar plantations of Louisiana, in the United States, with coal. This coal comes mostly from the city of Pittsburgh. It is floated down in barges in the spring and fall of the year to the various plantations along the Mississippi river and tributary bayous where it is, at present, unloaded over the raised river banks or



ANOTHER VIEW OF A CONVEYOR PLANT.

levees by means of wheelbarrows and negroes,—a slow and expensive way at the best. To meet the demand for a more expeditious and economical method of accomplishing this same object, a floating cableway was devised and patented by Mr. A. H. De Camp, of Trenton, N. J., and the first plant expressly for the purpose, and illustrated on this page and on page 454.

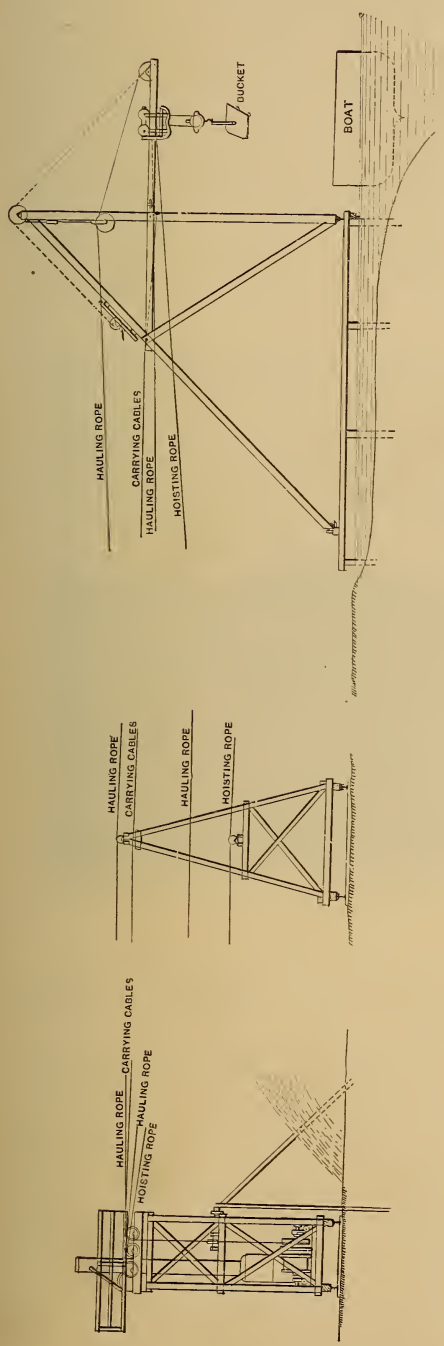
The method of setting up this apparatus and of operating it is as follows:—Previous to the arrival at the plantation, the foreman in charge visits the place and selects the two points between which the line is to run. The first of

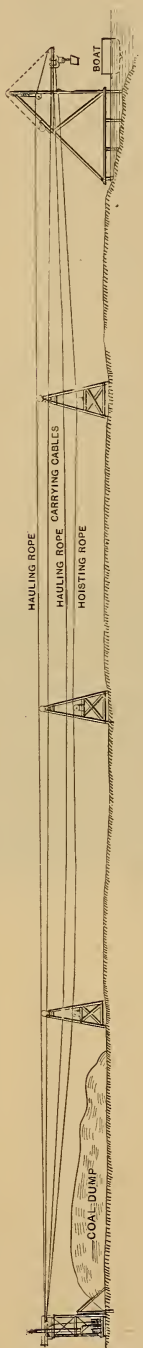
A MACHINE BOAT.

was built by the Trenton Iron Company of the same city, for Desforges & Jung, large coal operators of New Orleans.

The general arrangement and method of operating are similar in many respects to the dock cableway above described, but in this case everything is designed with a view to portability. The main structure consists of a frame tower, which, with the operating mechanism, is mounted upon a barge, designed

these is the proper location for the shore-end anchorage, and the second the best position for the machine-boat in front of the river bank or levee. The first is easily selected, but the second requires some judgment, especially when operating along the Mississippi proper, as it is necessary at times to take into consideration the matter of a current flowing at the rate of five miles an hour, and a rapidly rising or falling stage of water. Any one acquainted





GENERAL PLAN OF A CABLE HOIST FOR UNLOADING BOATS.

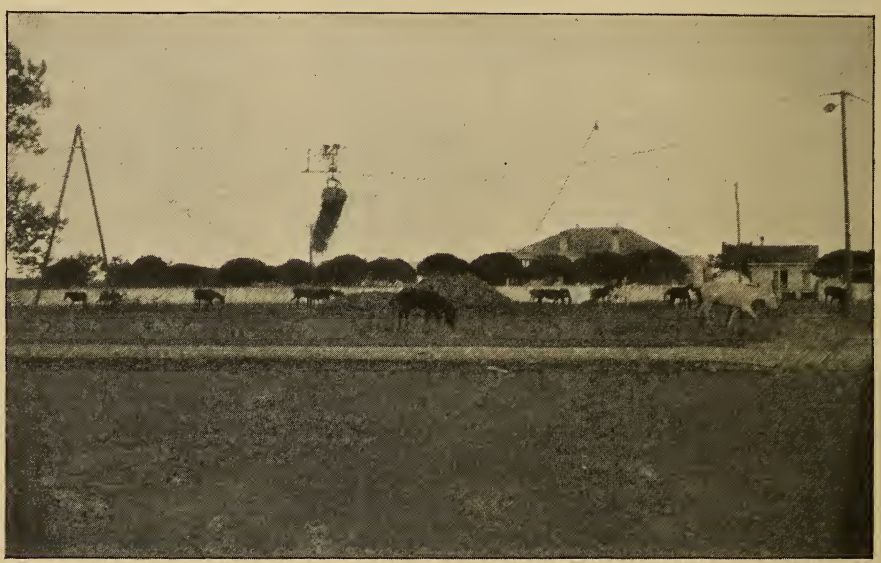
with these features of that river will appreciate this point and be the better able to judge of the efficiency and adaptability of the plant when informed that it has successfully met the severest tests in this particular.

The foreman marks the two points selected and, if possible, at once sets a couple of men at the work of excavating for the shore anchorage. This usually consists of a "dead-man" or sunken log, which is conveniently procured from the coal boat in the shape of one of the heavy check posts with which these boats are provided. This log is buried about five feet and is permanently covered. Means of attaching the main guy rope to it are provided in the shape of a heavy U-bolt, the loop of which projects a little above the surface of the ground. As the logs generally lie in water and as the U-bolts are heavily tarred, it is supposed that this anchorage when once put down will last for many years.

When the machine boat has been brought to the proper position, bow and stern lines are run ashore and secured, and the end of the inshore boom or strut is dropped to the bank or the river bed, as the case may be. It will be readily understood that if the inshore strut has been properly placed, it

becomes a pivot around which the boat is swung into proper alignment by means of the bow and stern lines, which are worked by winches on the machine boat. If the end of the boom, from necessity, comes against mud or soft ground, a piece of gunwale from an old coal barge furnishes a ready means of making sufficient base to prevent the end of the boom sinking too far. Simple means are provided for attaching this bearing timber to the end of the boom so that it will go down to place with it, and, on the other hand, when the boom has to be raised it separates readily from the bearing timber which remains stuck in the mud. Considerable trouble was apprehended from soft ground in this connection, as the boom must withstand a heavy tension in the cables. Without some such simple provision, the end of the boom would become solidly anchored, whereas by the arrangement described no difficulty has been experienced in the softest bottom.

While the boat is being properly placed, the ends of the hoisting and hauling ropes are run ashore and the end of the latter is passed through a tail block which generally lies flat on the ground and is hitched to any convenient tree or stump as near in the line of the cableway and as close to the place selected for the "dead-man" as possible. If the latter is already in place, the tail block is fastened to the projecting loop of the U-bolt. The ends of the hoisting and hauling ropes are fastened together, forming an endless line between the machine-boat and the shore terminal. A stout chain is fastened to the junction of the two ropes, and by this means all the material required for the shore part of the cableway is pulled directly to its final location.



THE TERMINAL POST OF A CONVEYOR PLANT.

It should be noted that everything, at the outset, is so stowed on the machine-boat that each piece lies so that it can be readily made fast to the drag chain in the order required, and everything is transferred with surprising celerity. At the location from which the illustrations on pages 448 and 454 were taken, the machine-boat lay 400 feet out in the stream from the levee, two stretches of water filled with drift and stumps and the remains of an old levee intervening. Notwithstanding these obstacles and a levee 15 feet high,

the transfer of the material was quickly accomplished.

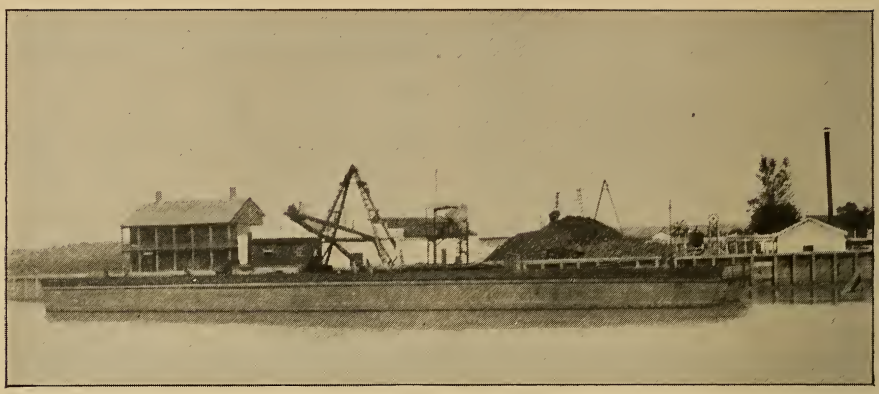
When all the timbers, guys, etc., have been sent ashore, the next step is to hitch the end of the main cable to the hauling rope and pull it out to the end support, close by the "dead-man." This support consists of a single stick of round timber, and has a snatch block hitched to it near the peak. The main cable is passed through this block and the end is pulled back to the boat and made fast. While the timbers for the supports are being hauled ashore, the final adjustments of both the inshore strut and the outward boom are made, so that, when the end of the main cable reaches the boat, everything is in readiness for it to be placed in its final position both in the top of the tower and around the sheaves provided for it in the end of the outward boom.

Thus far the support timbers have remained flat on the ground. Now the upper end of the terminal mast is raised about six feet and placed on a crotched stick, in order to give it a good start. Power is then applied so as to wind up the main cable, which raises the terminal mast to a vertical position, a heavy back-guy transferring the pull to the anchorage. It should be noted that the propping up of the terminal mast on the crotched stick is the only manual labour required, the several other operations being all performed by power.

While the main cables lie on the ground, the tops of the intermediate supports, which consist, each, of two inclined timbers, fitted with saddles near the tops for the main cable to rest in, are brought together over the cables and the tops are bolted. When the end mast is up and properly guyed at the sides, the main cables are tightened, which raises the head of the support next to the end mast from the ground. The hoisting rope is then fastened to the top of this support and the engine pulls it to a vertical position in which it is properly secured by light guy ropes. The operation just described is repeated for as many supports as are required till all are raised and guyed. The supports are about 35 feet high, but a pair of shorter timbers are provided, in case it should be necessary to put a support on the levee. When the supports are all up, and the main cable is placed in the saddles, a final tension is applied, the drum being geared to wind against a pull of 20,000 lbs. This drum is then disconnected from the engine by means of a clutch. The carriage, which was secured in the top of the boat tower, is now placed on the main cable. The ends of the out-haul and hoisting ropes are then made fast to the frame of the carriage, the latter after being rove about two sheaves, one in the carriage and the other in a fall-block to which the buckets are hooked.

The empty buckets are then transferred to the coal barge, which, during the operation of erection, has been moved into place alongside the machine-boat, the latter lying between the coal barge and the levee. A bucket having been loaded, the fall block is hooked to it, and both are raised till the fall-block engages a latch in the carriage. The engine, of about 30 horse-power, is then reversed, winding in the out-haul rope and paying out the hoisting rope, which moves the carriage toward the shore. When the carriage reaches the dumping point, an automatic trip, suspended from the main cable, releases the latch of the coal bucket, allowing it to turn over and discharge. The engine is then again reversed, and the hoisting rope pulls the carriage with the empty bucket back to the boat. Arriving at the end of the outward boom, the carriage comes against a stop, whereby the fall block is detached, and the bucket is lowered. A full bucket is in readiness to be hooked on immediately, and the operation is repeated. The buckets hold a ton of coal each.

In taking down the cableway, the erecting operations are simply reversed. At the "set-up" illustrated by the engravings on pages 448 and 449, the distance from the machine boat to the levee was 400 feet, and from the levee to the end mast also 400 feet, making a total run of about 800 feet. A round trip could be made over this distance in less than two minutes, that is, the line



UNLOADING A COAL BARGE.

is capable of a daily output of about 350 to 400 tons. This place was selected as the most difficult likely to be encountered, and was the second on which the apparatus was tried. Considering the experimental nature of the work, the inexperience of the men employed, and the natural disadvantages of the situation, the test was highly successful. The first plant has proved the entire feasibility of the thing, and the designer has now gone further, and added the feature of machine loading of the coal buckets, the lack of which in the plant just described militated very much against its best efficiency.

AFTER UNLOADING.

MODERN METHODS OF STEAM ENGINEERING.

By W. H. Booth.

IF a review be taken of the whole practice of steam engineering, from the time of Watt to the present day, no fact will be more prominent than the one that, within the mechanical possibilities of his time, Watt did almost every thing that could be done to economize steam. The very essence of his invention was not, as many would suppose, simply a question of a separate condenser and air pump, but neither more nor less than to maintain the cylinder as hot as the steam which entered it.

It can hardly be supposed that Watt did not clearly perceive the mischief that arose from the presence of water in the cylinder in whatever manner such water may have entered it. The method that Watt adopted to keep the cylinder as hot as the steam was, to say the least, a very curious one to be adopted if we are to assume that he was not fully cognizant of the peculiar properties of the fluid with which he was dealing, for he made his steam jackets simply a portion of the main steam pipe to convey the working steam to the cylinder. First, the steam warmed the jacket; next, it entered the cylinder. The steam, in fact, warmed its own cylinder. Nowadays we use a separate quantity of steam, and yet we have less efficient jackets. But Watt was right. He aimed at keeping water out of the working cylinder, but did not mind its presence in the jacket, for he knew that the jacket must always be at boiler temperature and that there could be no alternations of condensation and re-evaporation within it. He also knew that the circular jacket would act as an efficient water separator, and, in this manner, he made use of the latent heat in the portion of steam that condensed in the jacket to prevent condensation in the cylinder.

It was but shallow criticism that condemned this type of steam jacket,—a criticism that did not appreciate the peculiar behaviour of steam in regard to its possession of latent heat. Watt must have had clear ideas on this subject, for, if he had not, then his steam jacket must have been a most egregious blunder. Granting him a proper knowledge, and his practice stands out level with the best knowledge of to-day, and the most accepted explanation as to the behaviour of water in reducing economy is seen, after all, to have been held by Watt one hundred years ago.

When the compound engine took its rise, it was early seen that it owed its economy to the subdivision of the range of temperature in any one cylinder, and what had been really an application of the principle of compound working was the Cornish cycle. In this the single-acting beam engine exhausted from the top to the bottom side of the piston without reduction of pressure and temperature below the terminal pressure, and, the top side valve being closed, the exhaust steam was allowed to fall to the pressure and temperature of the condenser. Thus, the working or steam side of the piston and the cylinder end were never exposed to steam of less temperature than that due to about 9 or 10 pounds absolute pressure,—a system that has been revived in the Willans high-speed engine, which exhausts from cylinder to cylin-

der via the opposite end of each cylinder, this engine being single-acting only.

But the advocates of the simple or single-cylinder engine would have none of the theory of the compound engine; its advocates were jeered at for "heat trap madmen," and, as a fact, early compound engines did very little to justify the faith in them, for too frequently they were supplied with steam of too low a pressure to be worth working through two cylinders. The gain in economy did not equal the increased frictional losses. There was less steam used per indicated horse-power, but there was more indicated horse-power to each thousand spindles or pair of millstones, and only as boiler makers produced a better and safer article did the compound engine obtain fair play. Even then the true reason of its economy was obscured, and we find Mr. Daniel Adamson, an engineer who, more than any other, placed English boiler making on a sound basis as a branch of mechanical engineering, and to whose untiring energy the people of Lancashire owe the great Manchester Ship Canal, actually building, twenty years ago, a quadruple expansion engine and supplying it with steam of only 100 lbs. boiler pressure. To the failure of these engines to give any better result than ordinary two-cylinder compounds is largely due the recognition of the principle of suiting the number of cylinders to the pressure.

The engineers of forty years ago have been instanced by Professor Unwin as clear-headed upon the theory of the steam engine. Possibly they still acted upon the teachings of Watt, for they aimed at keeping things warm, and even added heat to the steam itself so as to superheat it beyond the temperature of saturation, that is, beyond the temperature proper to its pressure.

The writer remembers reading a ponderous leader in a technical journal on the peculiar action of high-pressure steam upon cast-iron. The fearful results were laid bare in all their horrors, and as these results were contemporary with the use of superheated steam, this came to be looked upon askance, and it fell out of use as the compound engine grew in favour. Probably the true facts were that, as superheating was coming in when boiler pressures were becoming higher, the effects of the latter were attributed to the former, and so superheating was condemned.

It is now clearly recognized that the hidden mysteries of cylinder decay were those of rancid tallow and half purified vegetable and animal oils, and to-day, with permanent oils of mineral origin, very much higher pressures produce none of the dire results which had been looked forward to. That superheating was known to be an economy, the pages of Rankine sufficiently testify, but it was allowed to die, and the explosions of some boilers, in the town of Blackburn, in England, which had been "overflued" as a means to greater economy, was held as a sort of judgment upon the impiety of superheating. The truth of this explosion was, however, that the boilers were hung by their manhole mouthpieces upon the overflue arching and were, moreover, badly made and of poor material.

Then, superheating burned the packing and destroyed piston rods and was made to answer for so many other evils that it would have been useless to point out how very small is the amount of heat necessary to superheat steam or to explain how, before the piston has moved, all the superheat in the steam has probably disappeared and the engine is after all working only with saturated steam, dryer, it may be, than before, but still saturated.

Recent trials of a superheater in Alsace have shown a large economy with a perfectly safe and fairly durable apparatus, an economy of steam being the result, and some English experience with a new type of superheater appears to show that an apparatus, safe to so high as 150 pounds pressure, may be very successfully applied with great economy as to increased duty per pound of fuel. Still, owing to the superheated steam being subsequently deprived of its heat by passage through the water space of the boiler, very little extra heat

really reaches the engine, and no marked engine economy is recorded. Nevertheless the apparatus is there and only awaits suitable arrangement for the engine to benefit by its full use, and it is not now probable that so valuable an aid to reduction of water consumption will again be allowed to lapse from lack of appreciation of the true facts as to cylinder condensation.

The modern engine has such high speeds of rotation that very small quantities of superheat may be expected to tell upon the economy of working. The benefits arising from jackets do not increase with the speed of rotation, though, of course, the need for such benefits also falls off. Superheating, however, puts heat so directly where it is wanted and is, moreover, so much more correct in theory than jacket action, that it will be some satisfaction to the steam engineer to find to his hand, in the near future, reliable means of attaining so desirable an end.

DR. WILLIAM ANDERSON.

DIRECTOR-GENERAL OF THE BRITISH ROYAL ORDNANCE FACTORIES.

THE rapidly increasing complication of war material and the consequent difficulty of manufacture induced the late British Secretary of State for War, the Hon. E. Stanhope, to take advantage of the retirement of General Maitland, the first director-general of the British Royal Ordnance Factories, to appoint as his successor, not a military man who, at the best, could but be the mouthpiece of his subordinates, but an engineer of thorough scientific and practical training, whose whole life had been spent in directing the manufacture of mechanical appliances on a large scale.

Mainly at the instance of Sir Frederick Bramwell the choice fell on Dr. William Anderson, who at the time,—July, 1889,—was in active business as a member of the old established firm Easton & Anderson, of London and Erith, but who, nevertheless, was able, at the call of the War Minister, to make arrangements to take charge of the Royal Factories in August of the same year.

Dr. Anderson sprang from an old Newcastle family, a branch of which, in the middle of the last century, settled in St. Petersburg, for the purpose of carrying on what is known as the Baltic trade. He was born on January 5th, 1835, and was educated, up to the age of fifteen, in the High Commercial School of his native city. This school, founded and managed by a body of merchants of all nationalities, was peculiarly suited for giving a thoroughly useful education. Classical teaching was practically excluded, while the natural sciences, history, political economy, statistics, bookkeeping, and the modern languages were taught with care and success. In 1840 Mr. Anderson came to London, and became a matriculated student of the Applied Science Department of King's College. He went through the complete three years' course, obtained many prizes, and left in 1851, with the degree of Associate, in order to become a pupil of the late Sir William Fairbairn, at Manchester. He remained with Messrs. William Fairbairn & Sons for three years, and during that time was largely employed in the erection of outworks.

In 1855 he became manager, and very shortly after a partner in the firm of Courtney & Stephens, of Dublin, and in that capacity was very largely

employed in railway work, and especially in the construction of iron bridges, turntables, signal stations, water supplies, cranes, etc. He paid particular attention to the theory of diagonally-braced girders, then but little understood, and contributed several papers to the Institution of Civil Engineers of Ireland, of which body he was elected president in 1863. In the autumn of 1864, Mr. Anderson removed to London, and joined the old established firm of Easton & Amos, with the object of building new works on the banks of the Thames at Erith, the firm's old premises in Southwark street having been found inconvenient for large and heavy work. The Erith works have been gradually extended, and are now among the most extensive in the country, their position on the Thames and direct communication with the South-Eastern Railway system, affording exceptional facilities for the transport of material and for the execution of home and foreign work of the heaviest character.

Dr. Anderson's command in connection with the Royal Ordnance Factories embraces three factories in the Royal Arsenal at Woolwich, namely, the Laboratory, the Carriage Department, and the Gun Factory, and, in addition, the Royal Gunpowder Factory at Waltham Abbey, and the Royal Small Arms factories at Enfield and Birmingham. These factories employ about 17,000 men, and turn out work to the value of two and a-half million pounds sterling annually.

Dr. Anderson is a member of the Council of the Institution of Civil Engineers, a vice-president of the Society of Arts, past president of the Institution of Mechanical Engineers, a member of the Iron and Steel Institute, and of the Institution of Naval Architects. His knowledge of foreign languages, and especially of Russian, has enabled him to enrich the proceedings of the Institutions of Civil and Mechanical Engineers with many abstracts of foreign papers. He has translated the remarkable essays on steel by M. Chernoff, and the researches into the internal stresses in gun steel by the late General Kalakoutsky.

He was selected by the Institution of Civil Engineers to deliver one of the "Heat" series of lectures, namely, that on the "Generation of Steam," and later to inaugurate the series of "Forrest" lectures. Similarly, he was selected by the School of Military Engineering, at Chatham, for courses of lectures on "Hydraulic Machinery and on Hydropneumatic Gun Carriages;" and by the Society of Arts for a series of lectures on the "Conversion of Heat into Work." At the Newcastle meeting of the British Association he was president of the Mechanical Section, and had the honorary degree of D.C.L. conferred upon him by the University of Durham. In 1891 he was elected a Fellow of the Royal Society.

During his term of office he has been engaged in arranging many of the departments, in improving the systems of accounts and cost-keeping, and in the introduction of many new manufactures, such for example of that of cordite, which has already almost superseded black and brown powders; the construction of guns on Longridge's wire system, the substitution of cast and forged steel for cast iron in the manufacture of projectiles and the manufacture and repair of quick-firing ammunition cases.

Dr. Anderson speaks in the highest terms of all the members of his staff, both civil and military, as well as of all the employees and workmen in the Royal Factories. To their hearty cooperation and good will he attributes the success which has attended the introduction of the eight-hour day and the smoothness with which the change has been effected. He also speaks highly of the support he has received from his chiefs at the War Office, and from the officers of the Army and Navy with whom he is so closely connected.

THE OLD AND THE NEW.*

By Robert Allison.

IT is now about fifty-one years since I first entered a machine shop as an apprentice, in 1844, my first experience being in the shops of Haywood & Snyder, at Pottsville, Pa. The shops were considered as well equipped as any in the interior of the State; there were two or three slide lathes (not screw cutting) in the shop, but most of the turned work was done with the slide rest, and all the small turning was done with hand tools. There was one planing machine in the shop, the table being pulled back and forth with a common one-half inch chain. I recollect that this chain would break frequently, sometimes two or three times a day, so a number of open links were kept on hand to make quick repairs. The cross feed was automatic; all other feed directions were by hand. Those of you who have had any experience in a modern shop will appreciate the difference between those crude machines and the machines now in use. The work done in the shops was principally steam engines, and, notwithstanding the poor facilities, many good engines were turned out, some of which are in use to-day.

After working in the Pottsville shops about one year, I was sent to Danville, to the branch shops in that place, my masters having taken the contract to make the machinery for the Montour Rolling Mills, the first mills in the United States to make "T" rails. The mills were constructed under the supervision of Mr. Henry Brevoort—some of you may remember him, as he was located in New York after leaving the Montour Mills. I shall always have pleasant recollections of Mr. Brevoort, as he took special interest in me and my work, and would frequently insist on certain pieces of work being placed in my hands for execution; for, while I was only an apprentice, he thought that I did better than some journeymen.

The shop was equipped with two large lathes, thirty-six inch swing, mounted on heavy wooden shears, and the turning was done with heavy slide rests; there were also three smaller lathes on wooden shears, with slide rests, and two hand lathes, operated exclusively with hand tools; also one drill press and one screw-cutting machine—this constituted the whole plant.

The whole of the rolling mills proper were built in this shop, the engines being built in the Pottsville shops. In the early days of rolling mills, the engines were made with a long stroke, usually six feet, and the rolls were driven with gearing so as to get up the proper speed, the piston speed of the engines being about three hundred feet, the gear wheels being large in diameter; there were no facilities for boring the hubs, and they had to be keyed on the shaft with six or eight keys. This necessitated much clipping of key seats.

Shafts were all made of cast iron, of large diameter, with bosses in proper places for wheels; the bosses were turned off, and then eight flat pieces were chipped and filed true for keys; the wheel hubs were cored out about one and one-half inches larger than the shafts, and eight key seats cut of proper width and taper, according to the size of the shaft; then the wheel was staked on the shaft with four short wedges on each side, leaving four of the key seats clear. It required considerable skill to get the wheels true on the shafts, and but few were able to make a good job.

* Presented at the Detroit meeting (June, 1895) of the American Society of Mechanical Engineers.

After the wheels were staked on true, four of the keys were fitted and driven home, the stake wedges removed, and the other four keys fitted. Large cranks were fitted to shafts in the same way. The whole operation required a great deal of skill and unless a man was an expert chipper and filer he would make very slow progress.

The turning of large shafts was slow and tedious. The writer remembers having a cast-iron shaft ten inches in diameter and about ten feet long being given to him to turn on a hand lathe, with hand tools, the slide rests all being in use, the tools used being hook tools "V" and round nose, button and spike heads. Just imagine the feelings of a machinist of the present day if confronted with a job of that kind! I also remember another job that almost made me sick; this was forty set screws, one and three-quarters inch diameter, about four inches long; the iron was seamy and hard, they had to be turned from point to head and thread chased the whole length. You can hardly imagine the condition of mind I was in by the time I finished the last screw; and I think that if there had been about five more in the lot the country would have been obliged to get along without my services as a machinist, as I would have quit the business in disgust.

The chasing of screws by hand was one of the things we all had to learn. Starting the thread properly required considerable skill; drunken threads were common, and subjected the producers to considerable ridicule in the shop. All plane surfaces had to be chipped and filed, no matter what size, and good chippers were always in demand. Engine guides were made round because shops had no planers to plane them if made flat; and when the first flat guides were made, they had to be chipped and filed; connecting rod stubs were fitted the same way. Notwithstanding all these drawbacks very good work was turned out, some of which will compare favorably with the work of the present day. We still have some old-fogy machinists who claim that the work of the present day does not compare with old-time work, when accuracy and finish depended on the skill of the workman rather than on the accuracy and automatic operation of modern machinists' tools. The writer has considerable experience in old-time methods and with modern tools, and has no hesitancy in saying that the work of the present day is far superior to what was turned out by the old methods; but, as Mr. Holloway said in his remarks, the wonder is how such good work was turned out with the limited appliances at hand, and the mechanics of fifty years ago deserve more credit for their productions than those of the present day.

It may interest some of you to have a short account of how a steam engine was produced fifty years ago in the shops where the writer learned his trade. First a large drawing board was prepared, large enough to make a plan and side elevation, full size. Engines all being made very long stroke, the drawing boards were quite large; an engine of fourteen inches diameter, forty-eight inches stroke, taking a board about six by twenty feet. The engine was plotted down, lines chalked and leaded; patterns were then made to correspond to the drawings, castings were made and fitted, but connecting rod, piston rod, valve rods, etc., were left till the cylinder, guides and pillow-block were fitted on bed plate. Measurements were then taken for the different rods, and the rods made the proper length to fit. No two engines were exactly alike; variations in shrinkage and fitting were adjusted in the length of the rods. Generally, after the first engine was made, the drawings were planed out, so that the drawing board could be used for another size. This destroyed the record of sizes, but as all rods were measured for each particular engine, this did not interrupt the work of construction. I need not refer to the present methods in this line, as you are all familiar with them. To-day almost every part of an engine, or other machine, could be made in different shops, widely separated, and then assembled into a complete machine

without a hitch. This would have been impossible under the old plan. Taking all the disadvantages into consideration, the wonder is that the mechanics of fifty years ago could turn out as good machines as they did.

DISCUSSION.

Mr. Samuel Webbe.—When I first went to Lowell, in 1841, I made the acquaintance of old John Dummer, who had built all the wooden water wheels then in use there, and who came from the family from which "Dummer Academy," at Byfield, Mass., was named. Afterward, in 1847, I worked a year under Captain Phinehas Stevens, who built the "Bay State Mills," at Lawrence, Mass., and put in the last large "breast-wheels" used in New England, so far as I know. The old Masonic emblems of the "level, square and compass," were the principal apparatus used, and the "broad-axe" was one of the most familiar and useful tools. The old "surveyor's compass" was used in laying out the ground, and the "level" was practically as good then as now. "Lathes" for turning wooden columns, shafts, etc., had long timber beds, and were often set up in a convenient sawmill, and the tool, held in both hands had a long wooden handle which would reach back under the arm. Large curved work was usually "*scribed* out" on the attic floor of the carpenter's shop, and the "cooper's adze" and "draw-knife" were also important tools in working out these curves. Water-wheel shafts were usually made of wood with cast-iron "gudgeons," and cast iron in short lengths was generally used for shafts. These were usually square, but I remember when the late E. A. Straw of Manchester, N. H., who had been sent to England to examine mechanical matters, came home and fitted up one of the "Stark Mills," in Manchester, with hollow cast-iron shafts which were round. These were afterward taken out and solid wrought-iron shafts put in their place, which gave the mill an enormous load of unnecessary dead weight. Mr. Straw had been brought up by Mr. Boyden, of turbine celebrity, and had commenced engineering on the Nashua and Lowell Railroad.

The large pulleys of those days were all made of wood, on cast-iron hubs and spiders, a form to which we are now returning. Leather belts were made on the spot as wanted. There was no such thing as a ready-made belt in the market. All the mills and shops bought their leather from the tanners by the side and each establishment had its "belt-shop," where the hides were cut up and stretched, and afterward the edges "trued," and cemented, stitched or "pegged" together, wooden shoe-pegs being often used for this purpose. Machine tools were few to those of the present day. The iron planer had just been introduced, and the engine lathe was still a novelty. The first tool I ever worked on had V ways, which had been chipped by hand, and "draw-filed" to a straight-edge!

Donkey engines were unknown, and all heavy lifting was done by animal muscle applied to levers, or ropes and pulleys. Dams were usually built of timber, filled in with rough stone, planked on the upper side, and loaded with gravel, and were a prominent feature in the work of the millwright, as were also the flumes or feeders for conveying the water to the wheels, which were square, and made of planks, "keyed up" in timber frames.

Large pipe, either of cast or wrought iron, was unknown. When turbines came into use the feeders were often made round, of wooden staves, hooped with iron, like a barrel.

Mr. William E. Worthen.—It is my impression that not only the "large pulleys were built on cast-iron spiders," but that all pulleys were built up in this way in the early days, making a drum of uniform diameter for nearly the whole length of shaft, and that the shafts were of cast iron; and even if of wrought iron, nothing was turned except the journals. There was an advantage in these long drums, that the machines which they drove could be readily shifted laterally, and larger drums could be readily constructed on

them by board laggings when necessary for a change speed on the machines. The ends of these drums were closed to prevent dust from getting into the central space, and these ends were painted a dark green, which was a favorable color for the frames of machines, which were at that time invariably of wood, usually ash. All machinery of the Lowell Manufacturing Company was made after the designs of Paul Moody, at Waltham originally, afterward at Lowell, and no change was allowed to be made by any one except with his approval. At the shop there were foremen of the different rooms appropriated to the different machines, to whom the work was let by contract.

The machine-shop furnished, set up, and started the machinery of the mills. The superintendents of the mills were not mechanics or manufacturers. The machine-shop furnished machines and were responsible for their working. No alteration was allowed, and the superintendent had charge of the work-people. They compared the results of the same class of work in the different rooms of their own and other mills, took charge of the boarding-house keepers and the morals of the operators. Under these regulations the mills were a success ; but in 1831 Mr. Moody died. There were now many other cotton mills in operation and throughout the country, and soon the directors of the companies were alive to the new ideas, that there were other machines than their own, and which were improvements in the quantity or quality of the products.

I recollect when the first Whitworth planer was introduced at the machine-shop, and went to see it at work, and could appreciate the amount of chipping that it would save. Early in the forties the Lowell Manufacturing Company took a contract of the Reading Railroad for the construction of freight cars, of which the pedestals were made of a single plate of wrought iron and the jaws punched out by a hydraulic press. George W. Whistler came to supply Mr. Moody's place, and locomotives were undertaken at the shop, and I had the advantage of seeing the great trouble and trials in working out new designs much larger than the English ones.

Colonel Webber refers to *old* John Dummer ; he was about fifty at the time. As a millwright, he was the best I ever knew. His designs were good ; he took charge of his work personally, never talked but little to his men; in fact, never to any one unless it was necessary, and his work was joiner work. He would never loan on interest, as he called it usury.

He built the first wheels at Lowell in 1822, and none of them were, I think, ever renewed. The entire fall was at first thirty feet, which was used as a whole at the Merrimac Mills, but at the other mills in divided falls of seventeen and thirteen feet, as the power could thus be distributed, and sales of real estate extended. The wheels were of one type, wooden breast wheels with cast-iron shaft, in two pieces, coupled together at the centre, by a socketed hub ; on the journal ends there were large flanges with sockets. Three sets of arms were fitted to these sockets and braced from the ends to the central arm. The gates were horizontal, sliding over apertures leading vertically down to centre of the buckets, usually in three tiers, the lower one being detached except in cases of low water. Mr. Dummer continued to build these wheels till the introduction of Boyden's turbines, and, although the first ones had wooden flumes, he never took kindly to them or had much confidence in the results, and gave up his business as a millwright and removed to the country.

As the construction of turbines with the precision required by Boyden was then beyond the capacity of most of the mechanics at that time, Mr. Boyden attended to it personally. In testing the wheel every observation was made independently by two parties, nor was there any connection between other parties of the test, those at the weir with those at the wheel, and Mr. Boydon made separate observations of his own, with the notes of continuous ob-

servations. Thus complete, the percentage of effects at different speeds and openings of gate could be readily separated and calculated.

Mr. Boyden came of a remarkable family, strong generally, physically and mentally, of which Seth Boyden was another. In addition to his mental activity, he had wonderful persistence; without anything but a common school education, he made his calculations and design with the confidence, and the results were what was looked for, but not in money to him.

In his design and construction of the turbines for the Atlantic Mills of Lawrence, Mass., there was so much delay in construction that the company could not afford them for as long a test as he wished, and to determine the percentage of effect, which was a factor in his remuneration, a commission was appointed of Judge Parker, Prof. Benjamin Peirce and Mr. James B. Francis, who returned a verdict of considerable over ninety per cent. The factors of the calculation were head of water, speed of wheel, drawings of guides and wheel, and velocity of issue with its direction, that is as far as I recollect. Mr. Boyden made his calculation by arithmetic approximations, but as Mr. Francis told me, Professor Peirce said that the results were correct, but showed that the work of months by Mr. Boyden, with his usual checks by different calculators, could have been resolved in minutes by use of calculus.

At the Nashua Mills he persisted for months to find out the reason for the smaller percentage than what he expected, keeping his assistants at work during mill hours in the week and also on Sundays, and to their remonstrance that it had got to be monotonous, changed the dinner time of Sunday from half past twelve to one P. M. He found the why—it was the reduction of the depth of the guides about two inches.

Mr. Olin Scott.—The millwright of fifty years ago was the mechanical evolution of the preceding ages from the times of Archimedes, and was supposed to know everything pertaining to machinery and mills, from a watch movement to a fifty-foot overshot water-wheel.

Before describing anything pertaining to the methods and apparatus in use by millwrights in the past, it may be well to call attention to some of the methods and apparatus which we did *not* have at the time I first began working at millwrighting fifty years ago. At that time there were only three or four short railways in the country, and those amounted to very little as a means for doing business. Steamboats were the "*ne plus ultra*" of human achievement at that time. Just imagine this country to-day without its railways. At that time there were very few steam engines on land, and those used wood for fuel. I traveled a long distance to see the only one running, in a city of thirty thousand inhabitants in the State of New York. The telegraph was unknown. The planing machine for planing and matching boards, known as the Woodworth planer, was not in general use; and the Daniels planer, for planing timber straight and true, was only found in a few establishments, and the same may be said of the iron planer now used in every machine shop. The band-saw was unknown, and the circular-saw for sawing lumber was in but a few mills in the country. Many of the tools in the millwright's tool-chest were of the antiquated English style. No ready-made shafting or pulleys were kept on hand. Ready-made belts, crudely made, were just coming into use, and many belts were home-made. Rubber belting and other rubber goods were unknown.

No ready-made bolts or lag-screws were to be had. The blacksmith made all bolts and cut the threads by hand, making them cost fifteen to eighteen cents per pound and of inferior iron and workmanship; so that a good millwright, who then worked for $1.25 and $1.50 per day, would work a whole day to make some wooden device to save six or eight pounds of bolts.

Nearly all machinery was driven by water-power, and all good mills

used the overshot or breast wheels, except sawmills having the old-style vertically reciprocating saws, some of which used "reaction" wheels, and very few wheels of 100 horse-power were to be found. The largest and most powerful wheel in the country at that time was an overshot wheel sixty-two feet in diameter, at the Burden Iron Works at Troy, N. Y. At about the time mentioned, the first turbine wheels for heavy work were put in the cotton mills at Lowell, Mass. They were of the Fourneyron type, and gave good results; but the cost of such wheels placed them beyond the reach of most mills in the country for many years, so the only millwright was left to plod along in his old way for some years, building overshot and breast wheels, with wood shafts, having cast-iron "gudgeons" for bearings, which wheels most of the mill owners believed could not be equaled for efficiency, to say nothing of being superseded by the "new-fangled" iron wheels, as they were called.

In those days, if a water-power was to be developed, the millwright was the man who engineered the building of the dam, races, flumes and wheel-pits; determined the size of water-wheels required, designed the buildings, located the machinery and arranged the shafting and gearing, also determined the sizes of the gears, shafts, pulleys and belts to transmit the power to the several machines.

Large pulleys of six feet diameter or more were little used, and were mostly made of wood by the millwright, and large belts such as now universally used were not made, cast-iron gears and frequently cast-iron shafting being used for heavy transmissions of power. Mortise gears for wood teeth were occasionally found, but could be made only by a few shops in the country, and the rough iron pinions which worked with the mortise gears were fitted with cogs of no particular form, some of which were short-lived noisy affairs, while others would run well a long time. Many mortise gears were made by millwrights entirely of wood. I was once the owner of a grist-mill, which was fitted to grind feed (from corn in the ear), corn meal, buckwheat flour, and wheat flour, the mill having, in addition to the mill-stones, the usual outfit of elevators, "smutter," hulling machine, conveyor, Boults reels, corn cracker, and hoisting rig to take grain from a wagon at the door; and the only belts in the mill were the canvas belts in the elevators and conveyer, to which the cups were attached, and one leather belt to drive the smutter, for cleaning the wheat, and the mill run many years in that shape.

The great amount of experience or practice necessary to qualify a man to be a successful millwright required a large portion of a lifetime, and when we look about us to-day and see how the field of mechanical knowledge has enlarged from a little garden patch to a boundless prairie, and each branch has become a separate department of work more or less scientific in character, and requiring and employing men of the highest ability, we can realize that the progress has been simply enormous.

Yours truly
C. W. Cudlett

PAST PRESIDENT BRITISH INSTITUTION OF MECHANICAL ENGINEERS.

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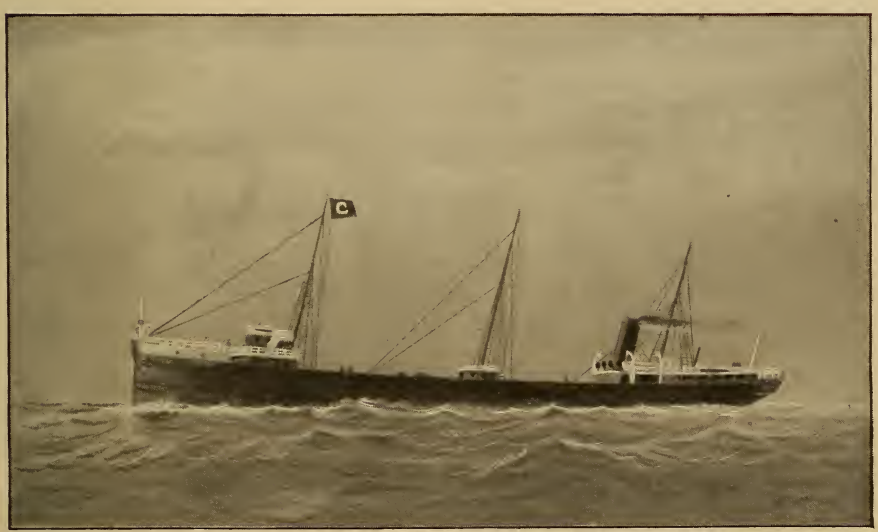

A TYPICAL AMERICAN LAKE FREIGHT STEAMER.

AMERICAN LAKE STEAMERS FOR OCEAN TRAFFIC.

By Joseph R. Oldham, N. A. and M. E.

THE latter part of the nineteenth century may be appropriately classed as the modern era of steamship canal construction, for, though the original Suez Canal may have been excavated about twenty three hundred years ago, during the reign of Darius the First, that ancient water-way was probably not projected, nor commodious enough, for the transit of large, deep steamers. Proceeding on the assumption that before many years elapse a water-way will be open between Lake Erie, in the United States, and the Atlantic, by which six-hundred-foot steamers, drawing over twenty feet of water, may safely pass between ocean and lakes, it may be well to consider the general efficiency or the degree of deficiency of American lake steamers for participating in the North Atlantic trade.

Perhaps no readier way can be found for ascertaining in what respects the

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THE AMERICAN LAKE PASSENGER STEAMER "NORTH WEST." BUILT BY THE GLOBE IRON WORKS, CLEVELAND, O., U. S. A. LENGTH, 388 FEET. BEAM, 44 FEET. TWIN-SCREW, QUADRUPLE EXPANSION ENGINES 7000 H. P.

lake steamers are deficient for such an ocean trade, than by comparing them with the typical Atlantic cargo steamer. Before doing so, however, let me say a word about this trade. In the North Atlantic it is not an uncommon experience for ships to encounter a succession of gales of wind, accompanied by very rough seas during the whole of the ocean voyage of ten or twelve days. This experience is not generally met with in any other trade. As a consequence, strong awning-deck steamers, like the Pacific Mail boats, which would answer well for the trade, say between New Orleans and the Mediterranean, are not sufficiently rigid for the more northerly course. Why this is so I cannot say, though I have heard it laid to the charge of the ubiquitous Gulf Stream, and again attributed to the irregular bottom of the Atlantic Ocean. Perhaps a useful result of this paper will be that some one may take the time to

give us a more lucid scientific explanation of the phenomenon, for as such it must appear to a layman who may reasonably ask why a vessel that is fitted for one ocean trade is not fitted for another. For the present I can only repeat in effect my former words, that a specially constructed steamer of extra strength must be designed to ensure a successful marine business between Northern Europe and Northern America.

With these plain facts in view, the extraordinary loss of life at sea, to which I shall refer, may not appear so unaccountable. In the year 1872, twenty-five British screw steamers were totally lost at sea. Many of these were lost in the North Atlantic, when loaded with grain, and two or three were known to have capsized before foundering. Fifteen of these were new steamers,—only about one year old. There were three primary causes for most of these terrible disasters:—1st. Deficiency of structural strength in proportion to the load carried ; 2d. The carrying of grain in bulk on top of empty ballast tanks ; 3d. Lack of engine power, for a vessel without engine power sufficient to drive her about fourteen knots an hour is not able to run before an Atlantic gale and heavy sea and keep above water.

Again, in the year 1881 not fewer than 1387 British vessels, aggregating 385,166 tons, were totally lost at sea. This tonnage amounts to nearly one-third of the total American lake tonnage, and

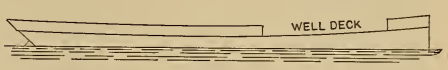


FIG. 1.

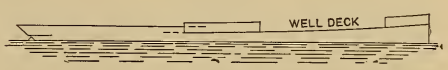
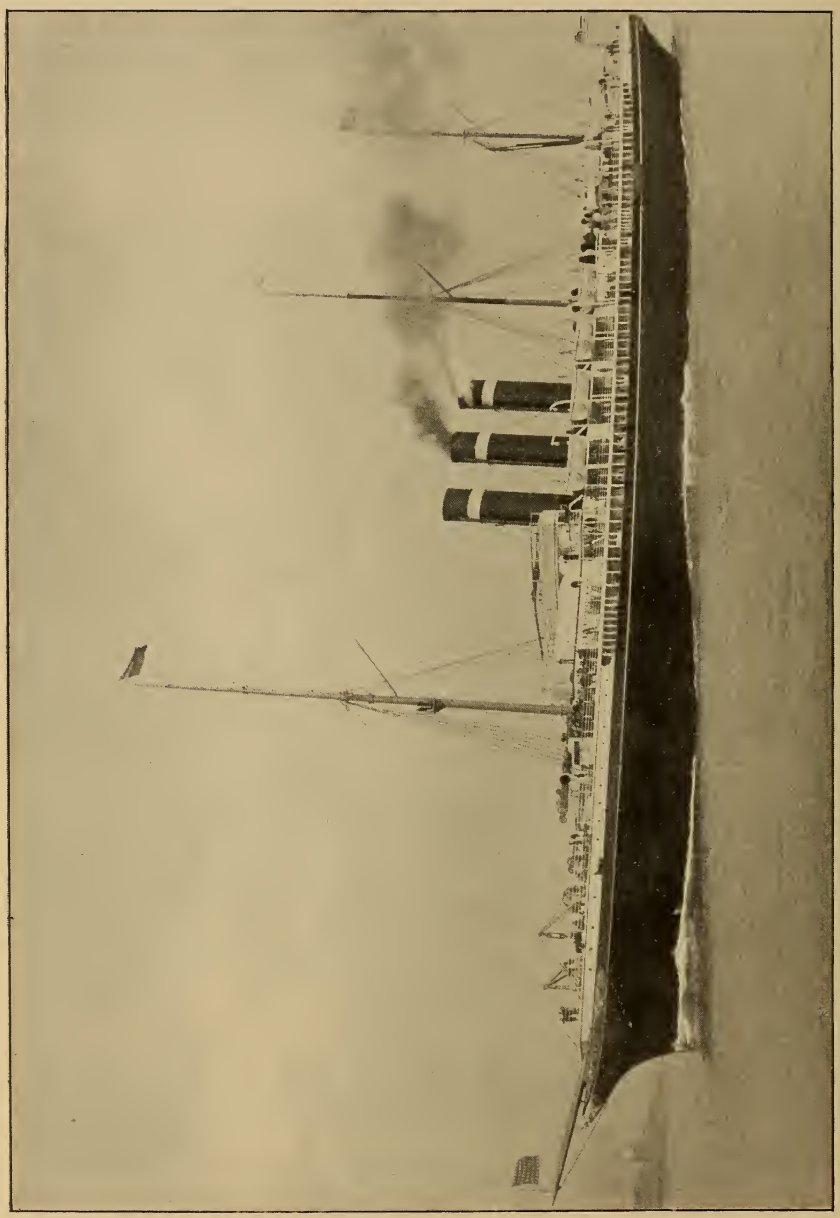


FIG. 2.

exceeds by 84,291 tons the total ship tonnage constructed on the North East Coast of England during the previous year. Many of these steamers were also lost in the North Atlantic trade, and that largely, no doubt, because they were deficient in engine power. But they were also of very light construction, faulty in design and ill equipped for standing upright when loaded with grain or coal.

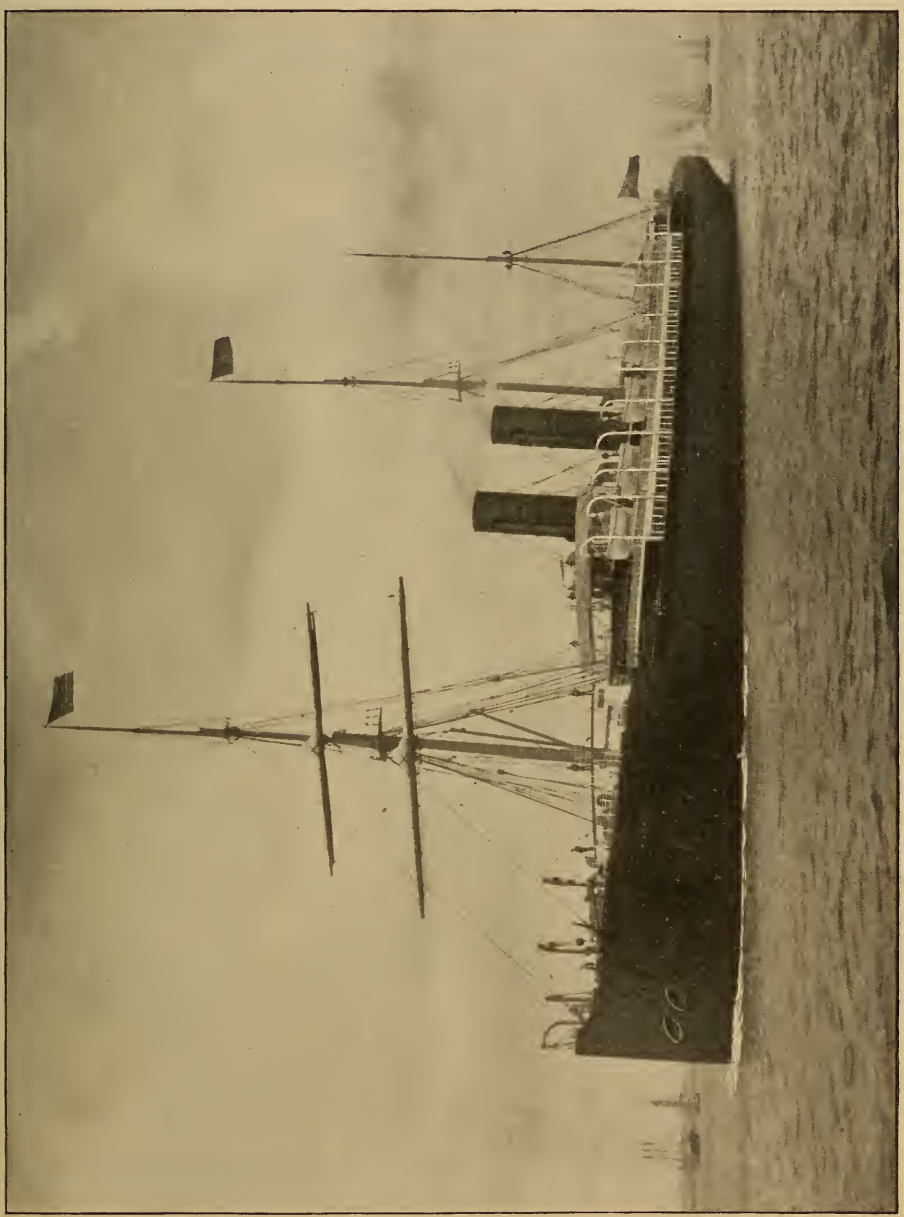
Most of them were of the full poop or raised quarter-deck type, as per Figs. 1 and 2, respectively, and of about the following general dimensions, viz.: 230 x 30 x 18 feet, with compound en-

ANOTHER VIEW OF THE "NORTH WEST."

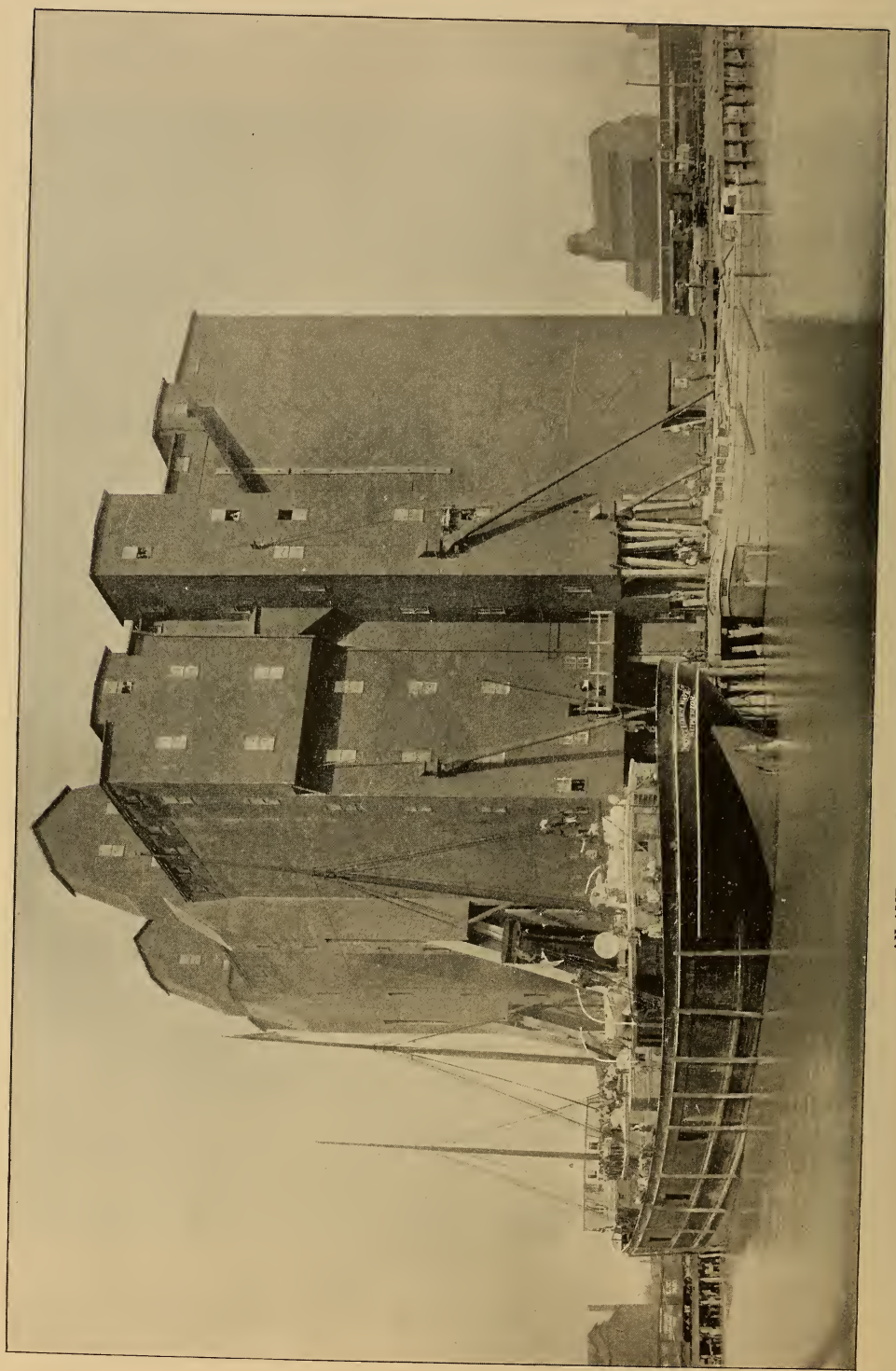


TYPICAL ATLANTIC PASSENGER STEAMERS.

THE AMERICAN LINE STEAMER "NEW YORK." LENGTH, 575 FEET. BEAM, 63 FEET. TWIN SCREW, TRIPLE EXPANSION ENGINES. 20,000 HORSE-POWER.



THE CUNARD LINER "AURANIA." LENGTH, 470 FEET. BEAM, 57 FEET. THREE-CYLINDER COMPOUND ENGINES, 10,000 HORSE-POWER.



AN AMERICAN LAKE STEAMER RECEIVING A GRAIN CARGO.

gines, indicating not more than 500 horse-power. The total number of lives lost in these 1387 disasters was 3836. I go thus fully into a description of the North Atlantic trade, because I have known experienced shipowners place spar-decked and even awning-decked steamers in that trade, upon the assumption that because such vessels were first-class of their kind and had rounded the Horn or gone to the West

THE MAIN SALOON OF THE "NORTH WEST."

Indies with impunity, they could also trade between the British Isles and New York without undue risk. This, however, is an error. Only special vessels are fitted to regularly work in that trade. From this it should seem that any experimenting with ordinary American lake steamers in the Atlantic Ocean, particularly in the fall of the year, would be hazardous in the extreme.

As a regular Atlantic cargo liner I will quote the general dimensions of the steamship *Sedgemore*. She is 406 feet in length, 46 feet in extreme breadth, and 29½ feet deep. Her engines are of the triple expansion type, with cylinders 30 inches, 49 inches, and 81 inches in diameter, respectively, and with a common stroke of piston of 60 inches. This steamer carries 6500 tons dead-weight, and steams 14 knots an hour. This is one of twenty-five steamers, the aggregate tonnage being about 50,000, managed by Messrs. William Johnston & Co., Limited, of Liverpool, England. A peculiarity of this vessel property is that every steamer is owned by a separate company, though all are worked or generally managed by Mr. William Johnston and his brother.

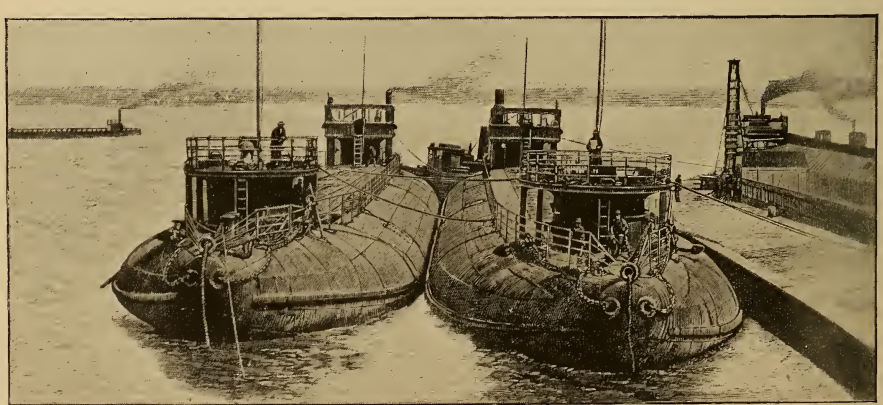
The largest steel American lake steamer at present under construction is 420 feet in length, 48 feet breadth of beam, and 28 feet moulded depth. She has twelve cargo hatchways, each measuring 32 x 8 feet, and will carry 7000 tons dead-weight on 20-foot mean draft of water. The propelling power consists of four cylindrical or Scotch boilers, each 120 inches in diameter by 11 feet long. There is one set of triple expan-

AN AMERICAN LAKE "WHALEBACK."

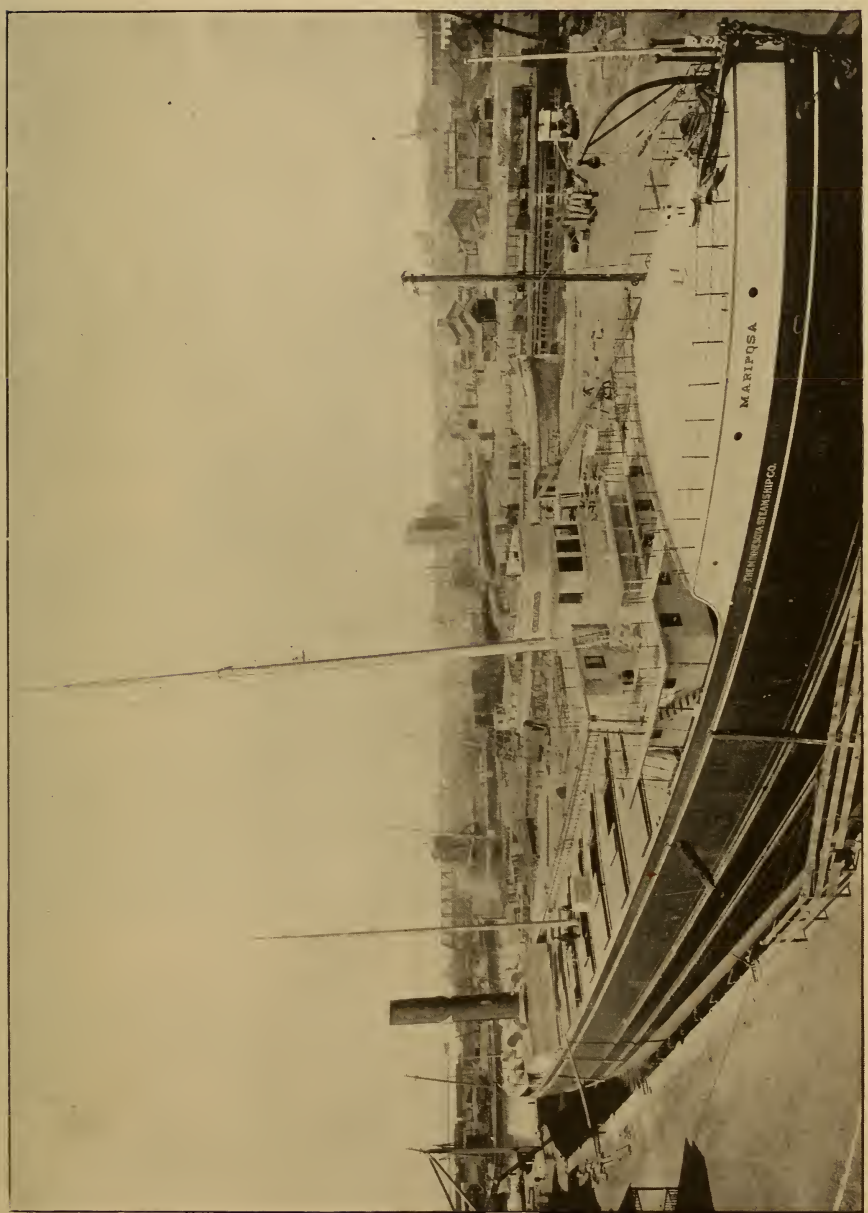
sion engines ; diameter of cylinders, 24, 39 and 63 inches, respectively; common stroke of piston, 42 inches; diameter of screw propeller, 14½ feet; estimated speed, loaded, 11½ miles an hour; capacity of water ballast tanks, about fifteen hundred tons. Over 3000 tons of steel are required for her construction.

The most striking feature of contrast in the general arrangement of lake and ocean steamers is in the location of the engines and boilers, and in the number and dimensions of the hatchways. The boilers of lake steamers are situated at the after end of the ship, and are fitted on a deck or platform raised to about the height of the main deck. Ocean steamers' boilers, on the other hand, are situated about mid-length and are fitted directly on to the ballast tank, or on top of the floors. When ballast tanks are omitted in the boiler room, the engines in both types are invariably located immediately abaft of the boilers. The ocean steamer is generally arranged with four hatchways, from 14 to 18 feet broad, and from 20 to 36 feet long, fore and aft. Lake steamers' hatchways are commonly 8 feet long (*i. e.*, in a fore and aft direction) and from 26 to 32 feet broad, and they range from six to thirteen in number, and have coamings usually about 1-5 of the depth of the ocean steamers' hatch coamings.

There are on these Great Lakes in the United States about 280 screw steamers, aggregating about 500,000 tons, which could be converted into ocean steamers, but whether the cost of such



WHALEBACK STEAMERS TAKING IN A CARGO.



A LAKE STEAMER IN DRY DOCK.

AN ATLANTIC LINER OUTWARD BOUND.

conversion would prove to be an economical investment or not, depends largely on extraneous maritime resources. It should be borne in mind that to compete with half a million tons of lake shipping there are five million tons of ocean screw steamers which are as well adapted to a combined ocean and lake trade as the American lake steamers are, and the channel which would permit of large lake steamers floating to the Atlantic, would be equally available for steamers of all nationalities entering these lakes, and, indeed, their general facilities for going this way are superior to those of American vessels for departing. Should the American lake carriers, however, eventually approve of the construction of a large deep waterway to the ocean, no doubt such a project could be consummated; but the lake shipowners are too astute to lend themselves hurriedly to any project that would inundate these inland seas with foreign shipping if they were unable to compete with such opposition.

Let us consider what the probabilities

are, so far as the efficiency of the hulls and machinery of lake vessels may contribute to the successful operation of a combined lake and ocean trade. So far as model or form is concerned, there is no peculiarity in modern lake steamers to unfit them for trading on salt water, though, as sea boats, an improvement could be made by lessening the breadth of beam, giving more dead rise to the midship body and increasing the "tumble home." The long parallel, almost vertical sides, tend largely to increase uneasy rolling, as these, coupled with great breadth of beam, produce an inordinate metacentric height ; but this may be lessened, in some instances, by raising the centre of gravity of the cargo.

The majority of lake vessels displace more water per inch of immersion when deeply laden than when partially or only lightly laden. This is owing to the absence of "tumble home." The exception to this rule may be found, however, in the "monitor" type and in the "whaleback," which displaces less water per square inch at 20 feet than at 15 feet mean draft. This anomaly applies to certain forms of ocean steamers also. Two ships, for instance, which just come to mind, displaced about five per cent. less water per square inch of immersion at 27 feet draft than they did at 20 feet draft. This is also the case, though in a lesser degree, in some P. and O. and Pacific mail steamers.

This feature of design is not objectionable, for its effect is to make a broad vessel an easier roller, in other words a better boat. To fit these steamers for the ocean trade, though the shell plating generally might be considered sufficiently heavy, extra strapping and riveting would be advisable in many cases ; new hatch coamings, deck houses, skylights and companions would be required ; a stronger rudder, new masts, spars and sails would be necessary ; and possibly some addition in the form of hold stringers and compensation for hatch-way openings would be asked for by the classification societies before recommending lake steamers for insurance while crossing the Atlantic. All this would increase the cost of the hull by about twenty per cent. The

IN MID-OCEAN.

BROADSIDE LAUNCH OF A STEAMER ON THE GREAT LAKES, U. S. A.

heaviest percentage of expenditure, however, would be in connection with the propelling power. A surface condenser is imperative for ocean navigation, and an evaporator for feed-water should also be added, for one of the highest-powered cargo steamers would require about two tons of "make up" water to be added per day to the boilers as supplementary feed.

If boilers, engines, all pipes, cocks and valves were absolutely steam and water-tight, and provided "surfacing" and "blowing" were abandoned, there would not be any necessity for a supplementary feed, for with the boilers properly charged with water to commence with, the same water, used over and over again, would be sufficient to keep up steam,—though it is quite possible that such water would become contaminated by continuous contact with copper and brass deposits and fatty acids, which would injure the boilers unless the internal surfaces were protected against corrosion and pitting. As it is, however, neither the materials nor workmanship at the disposal of the engineer are perfect; consequently the waste of steam and water is considerable.

In a gallon of sea water, equal to about 160 ounces in weight, there are 5 ounces of solid matter, about 85 per cent. of which is calcic sulphate, so that in every 32 tons of sea water, one ton of solid matter is held in solution; in other words, fully 3⅛ per cent. of the water is solid matter. From this it follows that for every thirty-two tons of sea-water forced into the boilers, one ton of solid matter is also brought in. This substance forms a scale and adheres firmly to the tubes, to the tops of furnaces and combustion chambers, and causes perhaps the greatest anxiety to a sea-going engineer; for, if this coating, when mixed with certain qualities of oil, becomes too thick, the furnaces and tubes may become overheated, as such scale is highly non-conductive, and might cause the internal portion of the boiler to collapse. On the other hand, should the internal surfaces of the boiler be absolutely clean, that is, devoid of any scale, corrosion and pitting of the steel must ensue; hence, the careful engineer, when starting out with new boilers, so arranges his supplementary feed of sea water that a thin coating of salt scale, say about one sixty-fourth of an inch thick, may adhere to the surfaces of tubes, tops of furnaces and combustion chambers to protect the

A WEST INDIA MAIL STEAMER.

metal. If, however, the surfaces do not take a scale,—and I have known such to be the case,—a systematic application of zinc in perfect metallic contact with the steel must be relied on to preserve the internal surfaces of the boilers.

The necessity for such apparatus as above described, is therefore apparent. A donkey engine connection, to keep the condenser cool and maintain a vacuum when the vessel is stopped, would add about forty per cent. to the cost of the engines and boilers, and as superior surface condensing, multiple expansion

ANOTHER DRY DOCK VIEW OF A LAKE STEAMER.

engines with copper piping and Scotch boilers, cost about $20 (£4) per horse-power, we may assume that about $8 (£1 12s. per horse-power would have to be added to the cost of lake engines and boilers to equip them for salt water work.

The coal bunkers would require material alteration, for although in the lake trade it is the custom to carry coal sufficient for the round trip, which occupies about five days under steam, whereas in the Atlantic trade it would be advantageous to carry coal only for the single trip of, say, twelve days, and assuming that an efficient surface condenser and feed heater would reduce the consumption of fuel about twenty-five per cent., still the bunkers which now contain only sufficient fuel for five days' steaming with a common jet condenser, would require to be double the size to hold enough coal for a twelve days' ocean voyage even with surface-condensing engines. Some spare boiler tubes and extra engine spare gear would be a necessity. An increase of the engine room and stokehold staffs would probably be required, as men in ocean steamers do not work watch-and-watch, except in an emergency. In addition to all this, seagoing certificates would be required by the master engineers and officers before lake steamers could be "cleared" for the salt water.

Now, though it is quite possible to design a steamer that would answer fairly well for a combined lake and ocean trade, such a vessel would necessarily be a compromise between an efficient ocean steamer and a first-class lake boat. A brewer's dray, though well adapted to its special work, would form but a sorry field-gun carriage, and a grand organ would hardly be appreciated for comic opera accompaniments; and so with mechanical devices, the most perfect machines are generally most limited in their sphere of operations.

However, though it may be impracticable to convert existing lake steamers into efficient ocean tramps, it will certainly not over-tax the enterprise or resources of lake shipowners and engineers to construct and equip a steam fleet of composite design, which shall be the superior of anything now afloat for that special work.

GAS AND OIL ENGINES.

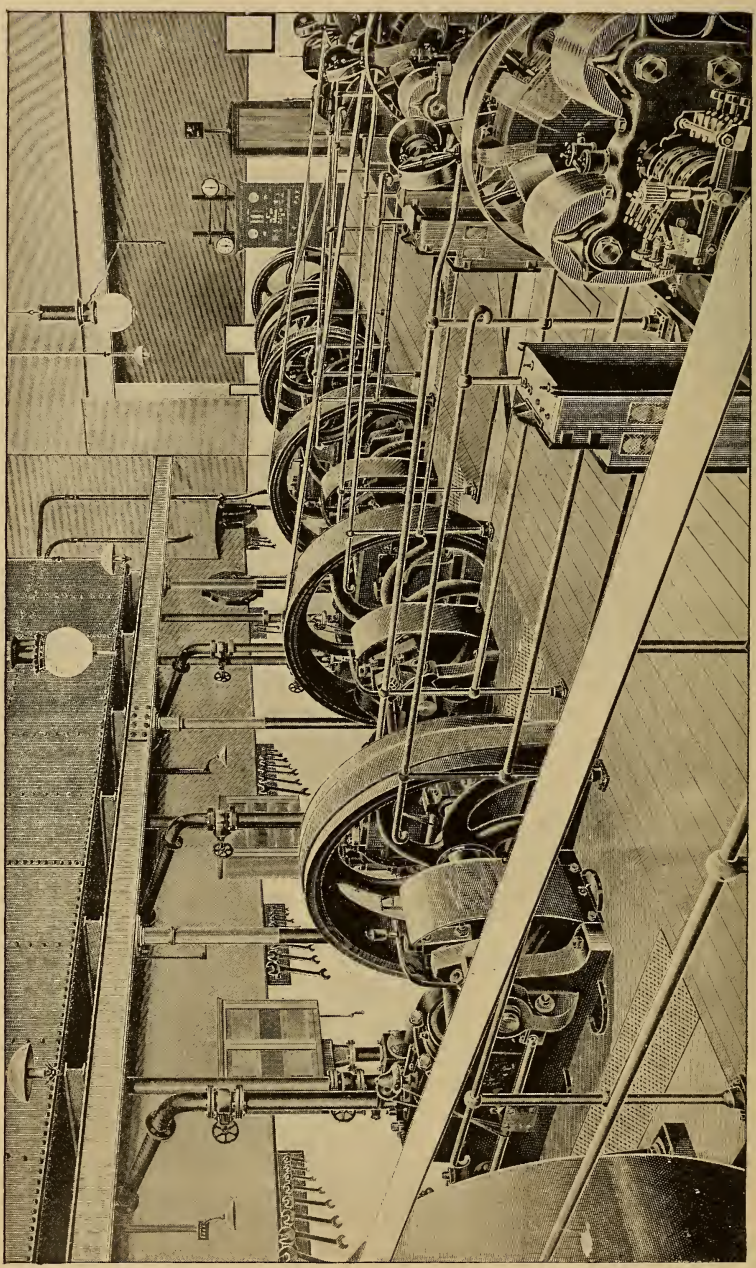
AT no time in the history of gas and oil engines has the interest in their application to every-day work been so strongly marked as at present. Together with electric motors, these engines have done much to displace small, and in many cases even large, steam engines, and power users have commenced to realize that for economical, reliable and convenient driving, engines of that class are entitled to very careful consideration. This is shown by every new contribution to the literature of the subject, and engineers' discussions of it at meetings of technical societies.

Among the latest, and perhaps most interesting, of these discussions is one which was held a short time ago before the American Society of Mechanical Engineers on the occasion of a "Gas and Oil Engine Evening," and to the facts presented at that time, and reproduced here, in part, it was thought well worth adding a number of illustrations of some of the most recent applications of the engines considered. These are all suggestive in their way and tell their own stories at a glance, more directly and more convincingly perhaps than pages of texts. The subject was introduced by Mr. S. A. Reeve who, among other things, said :—

"The status of the gas engine depends entirely upon the surrounding conditions. A plant exists merely because the sun shines, and the seed has been planted. Unless the surrounding conditions are favourable, the plant cannot exist, and the amount of its growth, and the character of its growth, depend entirely on the surrounding conditions. The gas engine follows this general law, in that its status to-day is what it has been forced to be, and what it has been allowed to be by general commercial and engineering conditions of the world. Practically all other power that is in use is steam power. I do not lose sight of the tremendous amount of water power that is in use. But water power is restricted to certain localities, and the gas engine is not. It comes into competition only with those forms of power which are applicable to almost any locality or set of conditions, and, aside from gas power, steam power is almost the only other occupant of that class of prime movers.

"The factory and the steam engine grew up together, and the idea that we carried in our minds of a commercial manufacturing plant, driven by any power, was a set of tools, driven by a central motor through the medium of a line of shafting and a number of belts. That scheme of industrial works grew in size and importance until it had reached tremendous proportions, and in certain lines of industry it still survives, and will continue to survive in the future in still larger sizes, and on a still more important scale. But for the vast majority of industries, these species of manufacturing which involve a varied number of processes and departments, and involve the production of a comparatively complex commodity, such, for instance, as the building of steamships or railway cars, or the complicated machines involving woodwork and ironwork and steel-forging work, and all that sort of thing, the modern factory is a collection of factories.

"The various factories may be merely departments, merely different rooms in one building or on one floor. But, at any rate, the factory now consists of a large number of departments, and those



CROSSLEY GAS ENGINE ELECTRIC LIGHTING PLANT, LEICESTER STATION, MIDLAND RAILWAY, ENGLAND.

departments are quite distinct. They often run entirely independently, have separate foremen or superintendents, run different hours, and have different classes of labour. In some, labour is a small item, and power is larger. In others, power is a small item, and labour is the principal feature. All these various conditions make it almost impossible for such an establishment to be driven by one central prime mover.

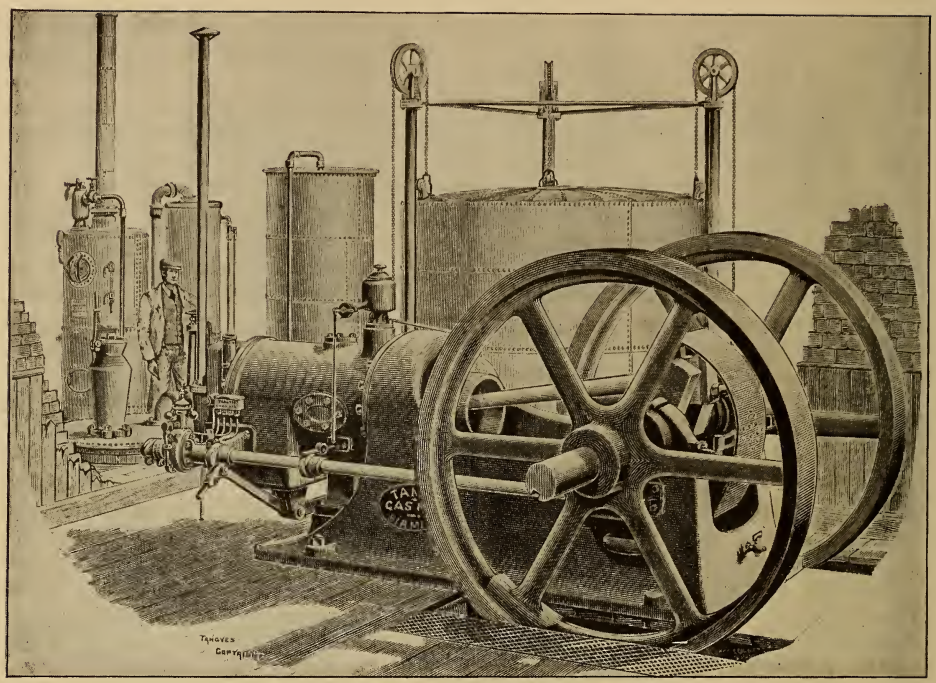
"In the first place, distance of transmission comes in and consequent losses. In the second place come in varying conditions. Every engineer knows that no piece of apparatus can work well under varying conditions. We have, therefore, seen grow up the modern industrial works in which power has to be transmitted quite a distance, and subdivided among a large number of different sorts of tools. This was first attempted by shafting and belting, or by rope drives. But it is evident that the losses by transmission are very great. Consequently we have seen other schemes tried. First came the subdivision of the steam engine itself into a large number of units, and we have only to look about us in large factories to see steam-driven plants where the power is furnished from the central boiler plant to anywh ere from ten or a dozen to 70 different engines scattered all over the works, sometimes 20 or more in one room. Sometimes the losses in steam transmission are, under average conditions, less than for shafting and belting. Of course, no cast-iron rule can be given for all conditions. But the subdivided steam plant has come in to stay. Of later years, superseding the subdivided steam plant, comes in, first, compressed air, and then electrical transmission and subdivision of power.

"I have given the résumé of the changes of the power question to show that the problem of the present is economical transmission of power, not economical development of power. Of course, economical development at the original point of production is of great importance, but it is vastly more important to transmit it economically, because the losses in transmission can easily exceed the largest losses possible in production.

"Those of you who have spent any time on the problem of the subdivision of power or its transmission, have seen that none of the systems heretofore provided satisfy the question. They all involve tremendous losses in transmission. They all involve heavy first cost, heavy expenditure for generating plant, transmission plant and redeveloping plant at the other end. For instance, in electrical transmission, if your total works need a thousand horse-power, besides your thousand horse-power of boilers, you must follow with a thousand horse-power steam engine, a thousand horse-power generator, your mains for carrying the electric power, and then, on top of that, a thousand horse-power of motors. That is, of course, losing sight of all small factors and percentages of loss. The present status of gas power, and also of its immediate promise for the future depends upon this statement of the problem in this part—that gas powers offers the ideal solution for the subdivision and transmission of power, the mechanical difficulties being, for the time, lost sight of.

"In other words, let us suppose that a large industrial plant requiring, say, 1000 horse-power, subdivided into, say, 50 different units which are utilized at various points, at different buildings, on different floors, at different speeds, for different hours during the day, under different conditions of varying and steady load—suppose that in such a plant as that, we install a 1000 horse-power gas generator or its equivalent, and then lead from it, or from the holder to a large number of gas engines, large central gas mains—it is evident that the first cost is away below that of any system, with the possible exception of the subdivided steam plant, where our boiler plant corresponds to our generating plant, our steam mains to our gas pipes, and our steam engines to our gas engines.

"But there is one big advantage which a gas plant has over a steam subdivided plant, in point of operation,



A 40 H. P. TANGYES GAS ENGINE AND GAS PRODUCER PLANT. BUILT BY MESSRS. TANGYES, LTD., BIRMINGHAM, ENGLAND.

and that is, that in the steam subdivided plant, no matter how large a proportion of the load be off, the central generating plant must be run, and the fixed charges of running cannot be altered. Steam must be kept up, the boilers must be kept hot, the stack, if there be one, must be kept hot, and the labour must be there to take care of the whole matter. I have myself tested one factory in which, for a large proportion of each day, the efficiency for the transmission of the power between the boiler plant and the work was 5 per cent., simply because they had to keep the whole plant going in order to move one small department.

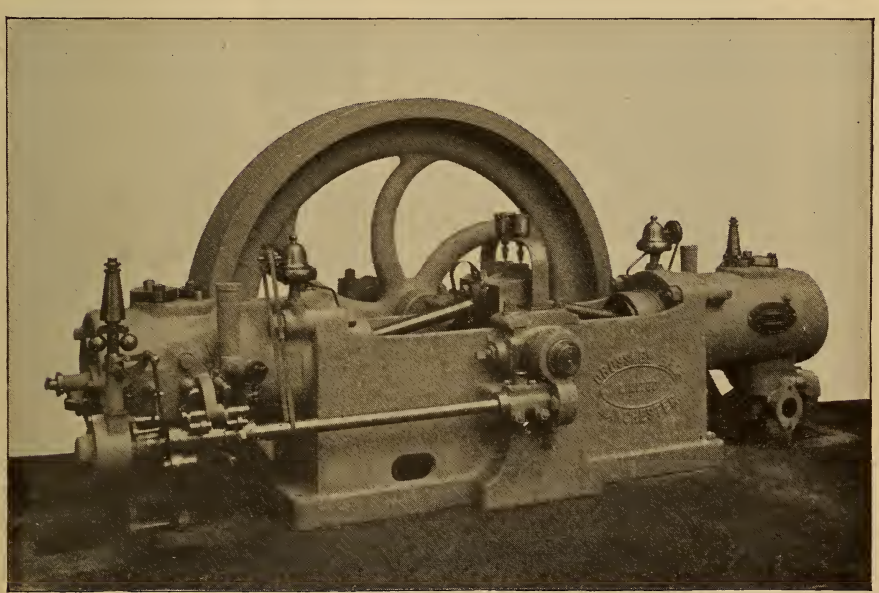
"With the gas plant that entirely disappears Your gas generator works for a certain number of hours a day, on whatever load or capacity is best suited to produce maximum economy, and as we all know, there is only one point in capacity in which any apparatus can work at minimum economy. During those certain number of hours a day the generator makes gas and stores it in the holder. The gas generating plant is entirely unconscious of the consumption of power, provided it be large enough to fulfill all demands. The consumers of power, the foremen of different departments, are as unconscious as is the generating plant of the consumption of power. They simply know that all they have to do is to turn on their gas and start their engine. They may run 24 hours in a day, while the gas generator runs eight, provided the total maximum production of the gas generator is large enough to cover the whole output of power.

"Comparison between such a gas plant and any plant relying upon transmission and subdivision of power by compressed air or by electricity, or by any scheme wherein the power is first developed by the steam engine, and then converted into another form, and then converted back again, is really hardly possible from the economical standpoint. The operation of any such

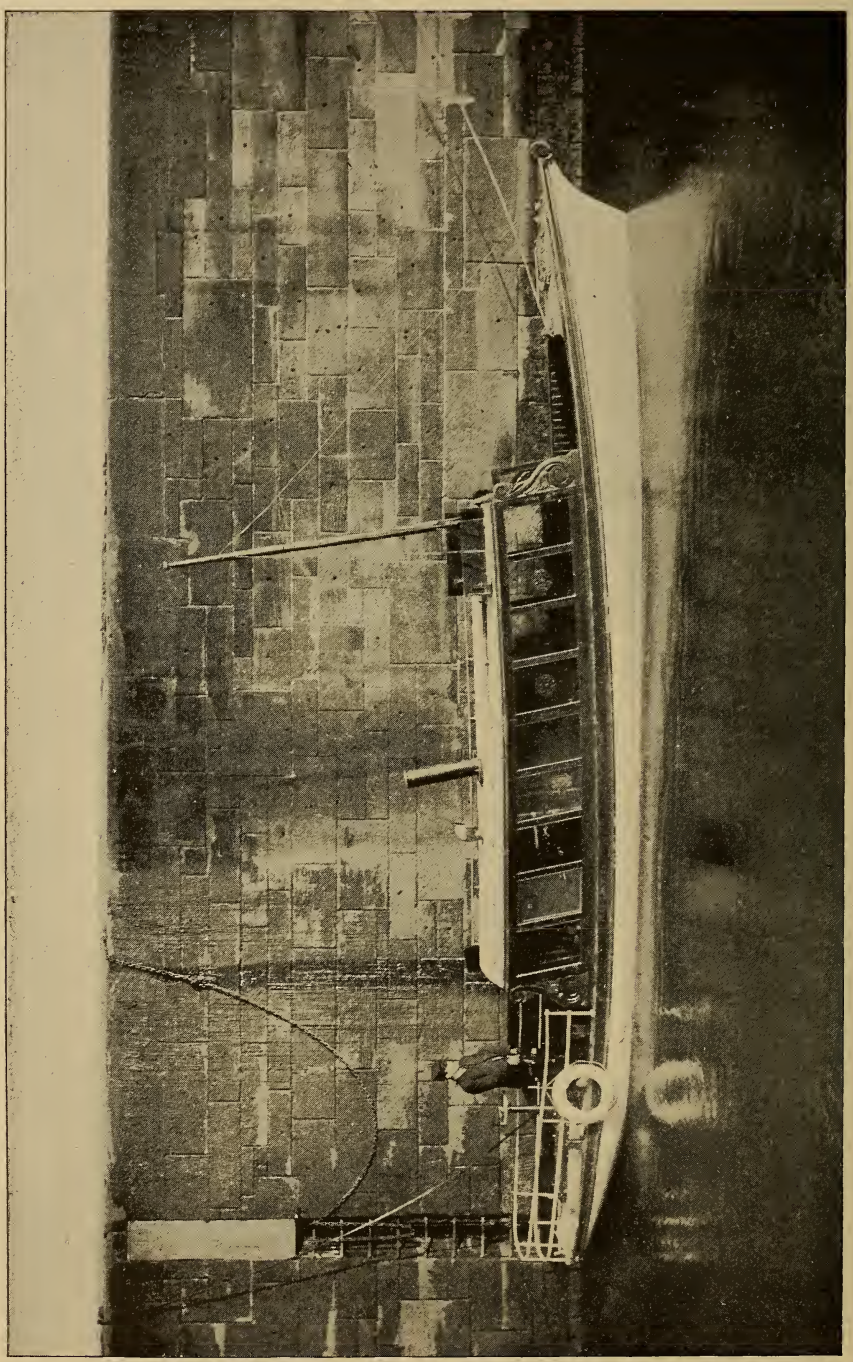
gas plant would be incomparably more economical than that of the compressed air or the electrical or the hydraulic system of transmission of power. I have entirely left out of the question the mechanical side of it, which I purposely wished to do. But for the merely commercial side there is an absolutely unlimited field for the development of power and its transmission and subdivision in industrial works by means of the gas generator and the gas engine.

"In nearly all large textile mills in New England, and in a great many other forms of industry, steam is used as much, and sometimes more, for heating purposes, and boiling and dyeing than it is for power. In fact, the big promoter of steam power in New England, where it has proved an indispensable auxiliary of water power, is the fact that the steam had to be had anyhow. That is true also of compressed-air plants. There are a great many factories where compressed air is indispensable for blowing, furnishing draft, cleaning, and innumerable purposes to which it can be applied, and in a great many plants compressed air is used to transmit and subdivide power where no other system would be tolerated, simply because the compressed air has to be there anyway, and, this being so, they might a great deal better use the compressed air for power.

"The same thing applies to electricity. Those factories relying on the electric current entirely for light may often bring the power question into secondary importance compared with light. If they have got to have their central engines and generators and mains for the productions and distribution of light, and if they need light more than power, then, of course, the electrical transmission of power is the thing, without regard to the general arguments against it. But this same factor of the correlation of the system of transmission of power, and the system of transmission of other forms of energy needed in the works, applies also to gas. In fact, the gas producer has reached its present state of perfection largely because of the fact that gas is the most economical form of fuel for a large number of industrial purposes—metallurgical, for glass works, and for many kinds of cooking and heating and baking, where exact control of tem-



A DOUBLE-CYLINDER OTTO ENGINE. BUILT BY MESSRS. CROSSLEY BROS., MANCHESTER, ENGLAND.



THE OIL ENGINE LAUNCH "PRIESTMAN," ON THE THAMES, ENGLAND. ENGINES BUILT BY MESSRS. PRIESTMAN BROS., LTD., LONDON.

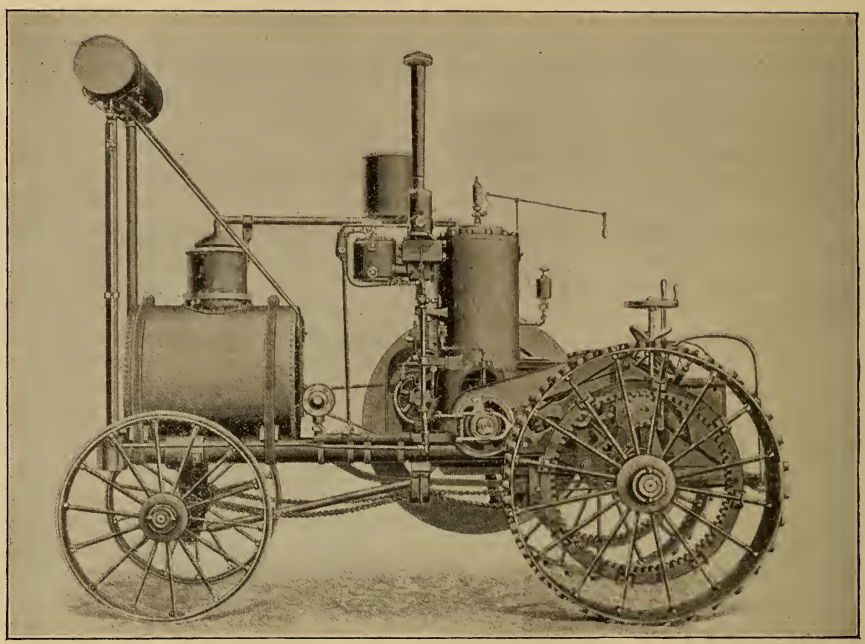
perature has to be had. In all those plants the power may again become secondary to other purposes in the factory, and in those plants where generators have already been installed for the purpose of supplying fuel gas, the gas engine follows as a natural sequence.

"The reply to this side of the discussion is that the mechanical difficulties have not yet been overcome; that the gas engine, after having had spent upon it the best energy in the line of mechanical engineering which the world has been able to produce for some thirty years, is still more crude in a great many mechanical features than was the steam engine of a century ago. It is still very heavy. In nearly all of the devices only one impulse is received by the fly wheel for every two revolutions, so that the fly wheels are heavy. The regulation, as a rule, is accomplished by simply dropping out a certain proportion of the impulses, instead of varying their strength, and the necessity for the ignition of the charge in a minute fraction of a second has led, until very recently, to extreme uncertainty in the matter of ignition and also in the question of perfection of combustion. The last is not so marked a feature, because, even with poor combustion, the gas engine is an exceedingly economical prime mover, but the mechanical difficulties still stand in the way of the accession of the gas engine to the proper field in which it belongs; that is, the universal factor for the production and transmission and subdivision of power in industrial works.

"At the risk of being considered rather superficial in skimming over this subject, I will take one step into the future and say that while gas engines have hitherto been almost entirely run with illuminating gas, yet already considerable has been done in the way of supplying gas engines with producer gas from special producers built for that purpose. There has also come upon the field—I will just mention it—the incandescent gas burner—that is, it has just begun to attract wide attention as being an established fact. These two coupled together—first, that the gas engine can be run much more economically upon producer gas, not illuminating gas, than it can upon illuminating gas, and, second, that there is a means attained of producing illumination by a non-luminous gas, lead us to the surmise that the near future will see the distribution of energy — all energy— which is derived from coal in the form of a non-luminous, cheaply produced fuel gas, that this gas will be relied on entirely for power, for lighting, where gas lighting at all is permissible; and where it is not, where the electric light is needed, that electric light will be produced through the medium of gas engines, and that this same gas will be used for all sorts of fuel and heating purposes—domestic heating and cooking and industrial heating of all sorts.

"I have tried to make as brief a statement as I could of the gas-engine problem as it appears to me to-day, not on the basis of the condition of the gas engine itself, but as a statement of its possibilities, the demands which are going to be made upon it in the near future, and what the near future may bring forth in the way of a powerful auxiliary to aid in the adoption of the gas engine as the universal prime mover."

Prof. Wm. S. Aldrich said: "Some of the chief difficulties to the extended introduction of the gas engine have been gradually removed by the improvements in methods and apparatus for the manufacture of producer gas on a small, yet economical, scale. In this, as in other branches of engineering, the law of supply and demand operates to mutual advantage, and isolated gas-engine plants are rapidly coming to the front. On the other hand, for the distribution of power from a central plant to greater or less distances, gas offers peculiar advantages. There are practically no losses in distributing the gas in pipe lines, except leakages, which can affect the economy of the distribution. Losses of pressure and temperature changes do not in the least affect the economy of the gas engine at the end of the line. Therefore, the distribution of power by



A GASOLINE TRACTION ENGINE. BUILT BY THE VAN DUZEN GAS AND GASOLINE ENGINE CO., CINCINNATI, OHIO, U. S. A.

gas, and its utilization by gas engines, scattered over a widely extended area, may come to be a rival of some of the other methods. And the facility of storage and use of gas for heating are additional advantages.

"It seemed doubtful for a long time whether gas engines could be made and economically managed in large units; but their present use up to 300-horse power and the contemplated manufacture of gas engines of 500 horse-power and upwards, leave no room for serious doubting. But it is open to discussion whether there is the same inherent gain in economy in the use of large gas engines as in the case of steam engines. Of course, on the general principles of power production, large units are more economical per horse-power than small units. Nevertheless, there is scarcely an argument advanced for the use of large steam engines that can be similarly advanced in the case of gas engines.

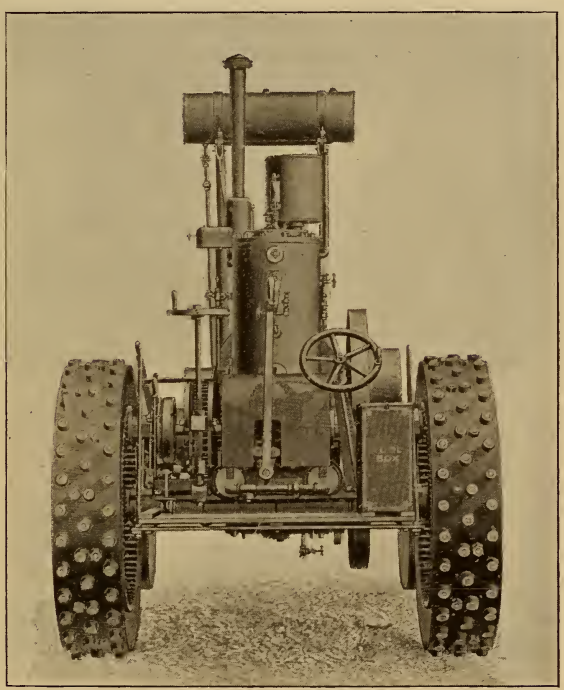
"In the matter of arrangement of gas-engine cylinders, there is undoubted preference manifested for the vertical type, and in pairs, with cranks at 180 degrees apart. Four-cylinder or quadruplex gas engines are being seriously considered, to gain an additional advantage along the same lines as the two-cylinder, or duplex type, namely, a greater number of explosions per revolution, and, consequently, an increased opportunity to control the supply and explosions according to the load.

"As rotating or rotary gas engines have been suggested, it may be well to note some of the advantages arising from using the explosions of the gas in much the same manner as the Pelton wheel utilizes the steadily applied impact of the water. The losses due to connecting rod mechanisms are eliminated; the highest speed may be obtained and controlled—especially to be desired in direct connection to dynamos; multiple discharge jets (or explosion pockets) may be arranged, as in the Pelton wheel; the force of the explosion may be most directly utilized in a tan-

gential manner; the internal friction will be reduced to a minimum; the best opportunities will be presented for regulating against the rapidly varying loads of electrical supply service; and, probably, a greatly increased economy will result in the use of gas.

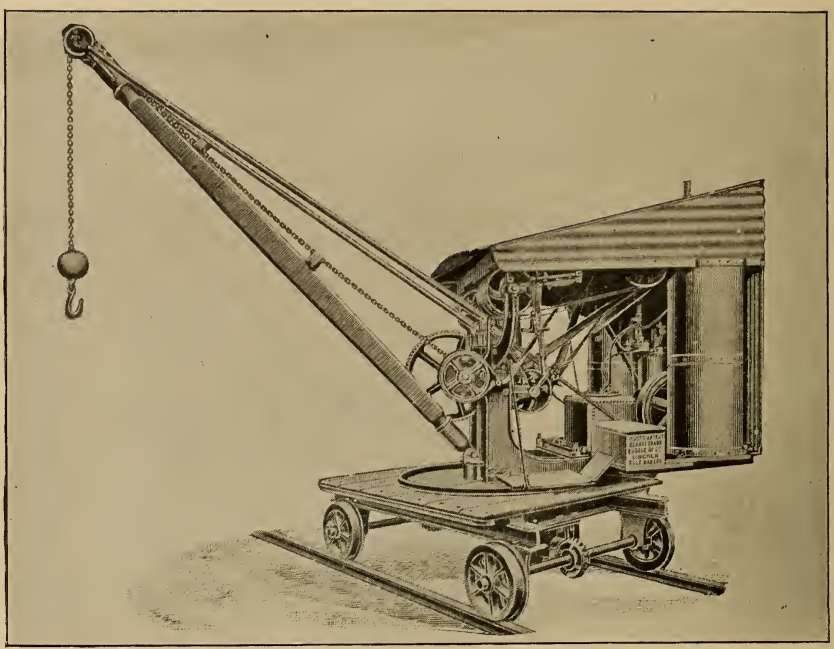
"In matter of speed regulation, gas engines have had an unenviable reputation, more due to the inherent difficulties of control than to any lack of inventive ability along this line. Always single-acting, frequently run at low speeds, and sometimes with rapidly varying loads, it is not difficult to understand that during one or more strokes the supply of gas may be entirely omitted, and the unusually heavy fly wheel drawn upon to meet the periodic variations in the supply of energy.

"Respecting the conditions of maximum economy in the use of gas, it has been found that there is a certain best load, for any given engine running at a given speed, at which load there is the least expenditure of gas per horse-power per hour. In this way it is possible to establish a very satisfactory basis for rating gas engines, that is, by their most economical performance. If gas engines could be tested and the curves of performance plotted, the whole gas-engine business would at once be placed on as satisfactory and substantial a basis as is now the case with turbines. The establishment of such a gas-engine testing plant is urgently needed. It would go far towards giving much needed additional encouragement to well-directed efforts in the development of the gas engine, as well as serve to forestall fruitless attempts in the same line."



FRONT VIEW OF THE VAN DUZEN GASOLINE TRACTION ENGINE.

Mr. W. Lawrence Wildy, representative of Messrs. Richard Hornsby & Sons, of Grantham, England, builders of the Hornsby-Akroyd oil engine, said:—"Most of you know, doubtless, that the producer is an ordinary cylin-



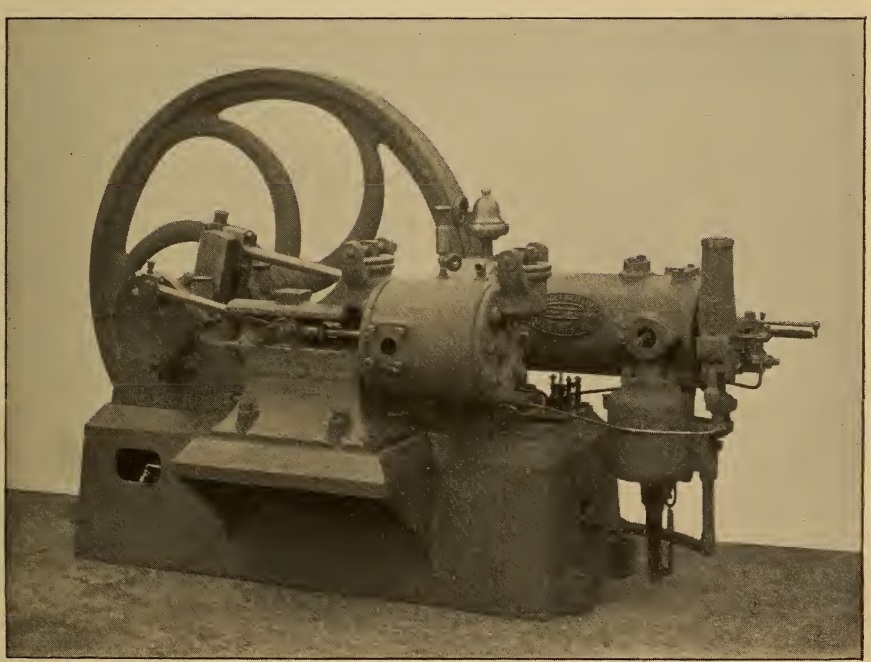
LOCOMOTIVE CRANE, WORKED BY A ROOTS OIL ENGINE. BUILT BY CLARKE'S CRANK AND FORGE CO., LTD., LINCOLN, ENGLAND.

drical vessel lined with fire brick, and more or less intricate in shape, according to the inventor's idea of what his patent is, and with certain cooling surfaces, or heating surfaces, or conducting surfaces, or something; but you will find 150,000 patents in the patent journal, doubtless, and they have all got something about them. But the simplest producer I have ever used was a column of fuel about 10 feet high. The fuel we used was coke—the coke which after distillation of the gaseous product was a residue which went to make the cost of the production of gas a mere cipher to the corporation running that gas concern. In Leeds, where I had my experience principally, the gas which was distributed through the houses cost nothing in the holder—it was all profit. I have seen the figures, and I have gone into it with the chairman of the Gas Committee of the Leeds Corporation, and it is a fact that it was a decimal short of nothing in the holder.

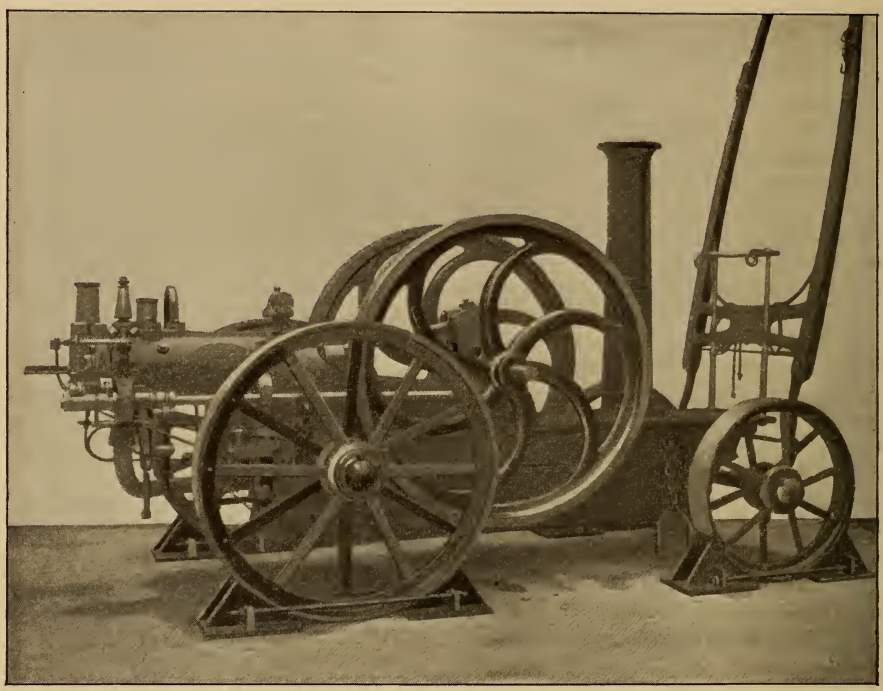
"The by-products from making the bituminous gas were so valuable at that time, that they paid all the expense, interest and depreciation of plant, and the gas in the holder cost nothing but distribution and collection of accounts. We were using enormous quantities of gas for welding steel tubes. We make tubes of varying diameters from 20 inches to 60 inches, and these varied in thickness from $\frac{5}{16}$ to $\frac{3}{4}$, and we welded these with the ordinary coal gas, and our gas bill ran from £6000 to £7000 a year. I got hold of this water-gas process, as it was used in Germany at the time, and I saw that it afforded a very good heating medium, very cheaply produced, and we went in for a plant there. The plant was a magnificent success, so far as we were concerned. It reduced our gas bill from between £6000 and £7000 to just over £1000 a year—fuel, interest, depreciation, labour, distribution—everything concerned came just over £1000 a year, or something under one-sixth of what we paid before. The gas cost us on an average about three pence halfpenny per 1000 cubic feet. We made

only water gas, but we got no by-products, and it therefore cost us something in the holder. In the water-gas business there are no by-products.

"In the oil engine we have a machine which works with the ordinary petroleum of commerce, that is, any of the lighting oils which are in the market. It will also work with the heavier oils up to the specific gravity of .9, and it will work with an oil having a flash point of anything that the ordinary oils have, and up to 320° Fahr. is a pretty strong oil. The process through which this oil goes to produce its power is as follows :—The engine is provided at the back of the cylinder with a small cylindrical chamber, which we call the vapourizer. On to this vapourizer is fixed a valve chamber, which really holds two valves, and which are the governour valves of the engine; the one opens inward to the vapourizer, the other opens by the action of the governour outward, and, through a small pipe, conveys any oil which is not required, back into the tank from which the pump has drawn it. The rest of the construction of the engine, so far as its communicating the power imparted to it is concerned, is almost identical with the gas engine—a trunk piston and connecting rod, and crank shank ; on the crank shaft a pair of skew wheels, the skew wheels driving a shaft—almost identical again with the gas engine—which shaft communicates motion, first, to the governours, and then to two valves, one for the air inlet, and the other for the exhaust ; the air inlet cam, at the same time, operates a small pump, from ⅜ to 1¼ inches in diameter, according to the power of the engine to be developed, and this pump has a stroke which can be adjusted by the regulation of the screw—that is, the oil pump—so that the amount of oil which is injected into the vapourizer is exactly in proportion to the power the engine requires. Suppose you are running the engine at half power, you run the pump at half stroke ; if you are running the engine at full power, you run the pump at full stroke, that is, if you know you are going to do so. But



A CROSSLEY OTTO GAS ENGINE AND AIR COMPRESSOR COMBINED.



A CROSSLEY OTTO PORTABLE GAS ENGINE.

if you are running the engine at full power, and throw off half the machines, the governour will do that, but the effect will not be so perfect as if you, knowing what you want, reduce it yourself. The exhaust valve has a double cam, very similar to that of the gas engine, by which a portion of the compression can be released when starting the engine. Now, in operating the engine you begin by heating the vapourizer with a lamp—an ordinary paraffin lamp with a circular wick—to which a small fan is attached, producing, for the time being, a little petroleum forge. It takes from five to ten minutes to heat that vapourizer. The only process is to fill the lamp and turn the fan handle. As soon as it is hot enough, you can turn your fly wheel, and your engine goes off at full cock; it is ready immediately, and it goes off at full power then and there, governing itself. The continual combustion of the oil in the vapourizer restores to the vapourizer the heat which has been extracted by the vapourization of the oil and the heating of the air necessary to produce the subsequent explosion.

"These engines have been running continuously for two months, day and night, without stopping, without any hitch whatever, and the higher the work that is taken out of the engine, up to full power, the better the engine works. At very low powers the engine will want a little nursing, perhaps, but at full power she will work right along. We start our engine at 5.30 in the morning, and the men come in at six o'clock, and she is never looked at again, except when the man goes in at dinner time and oils her, and at half-past five, when he goes to stop her, and there is no outside flame, no exposed red heat or dangerous flame of any sort about the engine."

Asked what he meant by nursing, Mr. Wildy said that if the engine had to run light for five or six hours, which probably no sane man would do under ordinary circumstances, it is possible that he may want to put a little brake onto the engine or some-

thing of that sort—to put a little work on her.

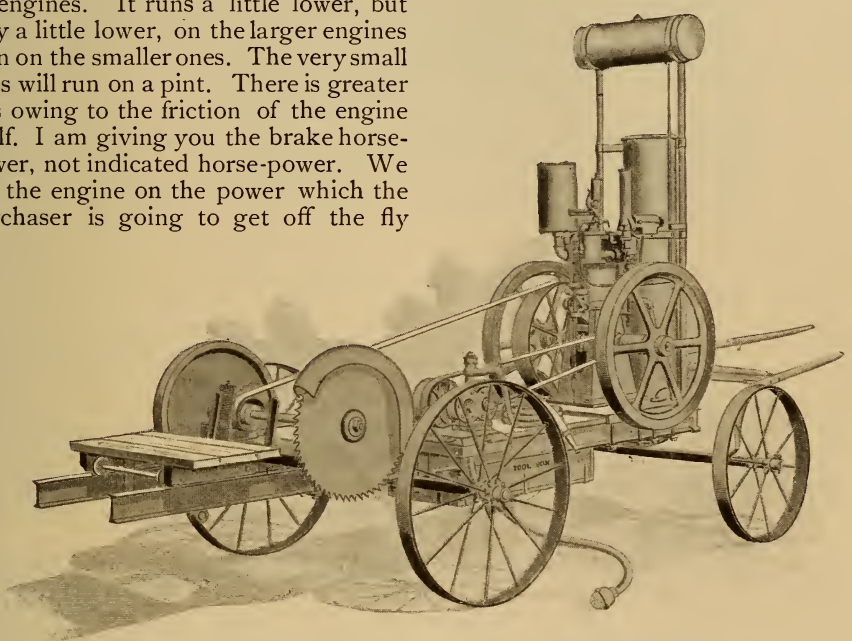
Asked if there was any residuum in the cylinder, he said :—"None whatever. We have run for two months and there was not as much as you could wipe off with your hand.

"The consumption runs about seven-eighths of a pint of American daylight or water-white per horse-power on all sizes of engines. It runs a little lower, but only a little lower, on the larger engines than on the smaller ones. The very small ones will run on a pint. There is greater loss owing to the friction of the engine itself. I am giving you the brake horse-power, not indicated horse-power. We sell the engine on the power which the purchaser is going to get off the fly wheel. He doesn't care what the power is in the cylinder. A 16 horse-power engine uses just .8 of a pint.

"In Russia they are adopting these engines and we cannot keep pace with them. With us in England it is a matter of consideration, because the oil which I understand you give about 7 cents a gallon for, costs us about 6 pence half-penny a gallon. They are doing wonderfully well with the engines over there. Every class of power-user is adopting them, to the rejection of all steam engines, up to 50 or 60 horse-power. They are in the hands of stablemen, gardeners, coachmen, all sorts of people, who, after they are once instructed, know what to do.

"The pressures in the oil engine are rather lower than in gas engines. In the Scotch gas I have had as much as 210 pounds initial pressure in the gas engine. The consequence is that the terminal pressure is so high that the exhaust becomes noisy."

The following discussion was contributed by Mr. Paul Winand, superintendent of the Otto Gas Engine Works, Philadelphia, U. S. A. :—



A VAN DUZEN PORTABLE GASOLINE ENGINE, SAW AND PUMP COMBINED.

"Concerning gas lighting by incandescent burners, I know by actual experiment that the temperature obtained from producer gas is not sufficient for the purpose. On account of the large percentage of inert gases which it necessarily contains, it is not even economical to enrich it for lighting purposes. However, by reason of the cheapness of the power obtained from this gas, electric lighting is generally the best possible way of providing light in such an installation. Pure water gas, though it can well be used in incandescent burners, is more expensive per heat unit, and, on the

whole, cannot compete with producer gas.

"It is generally thought that by increasing the number of impulses, the gas engine can be greatly improved as far as regularity of motion is concerned. This is only an argument of relative value, however, as the question resolves itself to this :—

"Whatever the number of impulses may be, there must be fly wheels of sufficient momentum to produce the desired degree of regularity. Now, is it cheaper, more economical and generally preferable to have a simple engine with a large amount of momentum, or a more complicated one with smaller fly wheels? The same regularity can be obtained in all cases, and it has not been proved that a simple engine of sufficiently high speed is not the more preferable solution. Considerable experience in this line has shown to me that it would be decidedly wrong to complicate the construction in order to get more than one impulse for each revolution. I should wish to emphasize the point made relative to the use of fuel gas for industrial heating purposes concurrently with its use for power. The advantages of gaseous fuel when applied not only on a large scale, as for metallurgical operations, but in smaller apparatus of various kinds, are being gradually recognized.

"A set of engines at Danbury, Conn., were built by the Otto Gas Engine Works with the provision that they could be operated indiscriminately by producer gas or by illuminating gas. The latter gas having about six times the heating value of the former, it will be easily understood that a compromise had to be resorted to in the construction, the result being that the engines do not give the best possible efficiency in either case. Engines built solely for producer gas would give better results.

"Since steam is used in the Danbury plant for various purposes, it was quite natural to employ a small steam engine for starting the gas engines. The large engines built now by us are provided with a self-starting device which renders the use of auxiliary power unnecessary and greatly enhances the convenience of operating the plant.

"The efficiency of a plant depends on the choice of the units of power, and perhaps a better result could be obtained in this case, if the units were differently selected. It should also be borne in mind that the producer used is large, and would be capable of furnishing gas for a greater amount of power, especially if the load factor was more favourable as it would be, for instance, in the operation of a mill or of a water-works, and I might well state here that gas power is being used extensively in Europe for the last named purposes.

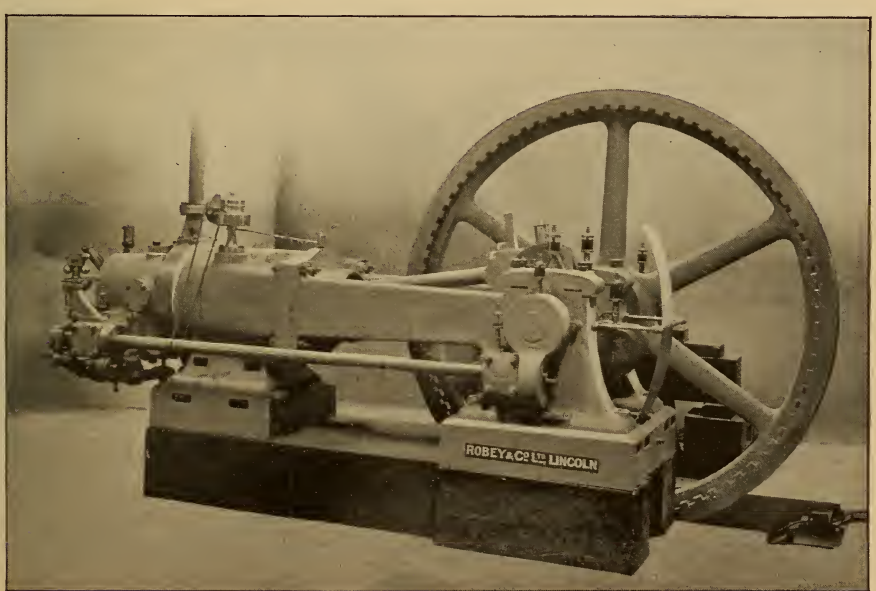
"Up to this date it has been customary to use a steam boiler in connection with the producer. This is not a necessity, however, and we operate in our works a producer plant without boiler. The necessary amount of water vapour which passes with the air through the producer is generated at atmospheric pressure by means of the waste heat of the gas as it leaves the producer. There is thus no additional fuel used for producing steam, and, besides, the operation of the apparatus is rendered almost automatic.

"Despite statements to the contrary, oil engines have been manufactured in the United States for several years, and considerable effort has been made for their introduction. We ourselves are fully prepared to begin their manufacture if a sufficient demand should arise. But in view of the fact that gasoline engines are so much preferable in most every respect, it is not surprising that the demand for oil engines should be so small. Gasoline engines have all the advantages of gas engines, and in some of those built in the United States to-day the provisions for safety are so absolute that the insurance companies have no objection to their use. Besides the objectionable smell which seems inseparable from the oil engine, there is the objection of its not being ready for starting at a moment's notice. Oil engines are naturally wasteful when running at partial and variable load. This is due to the fact that the proper de-

THE DAIMLER GASOLINE MOTOR CARRIAGE WHICH WON THE FIRST PRIZE IN THE PARIS ROAD CONTEST.

gree of temperature is not maintained at the different loads which occur in practice. When a continuous external flame is used for maintaining this temperature the fuel consumed in this flame decreases the efficiency at reduced loads.

"The oil engine described by Mr. Wildy was exhibited at the World's Fair. In this engine the ignition of the charge depends on the temperature of the chamber, which is left uncooled at the rear. The temperature of this chamber, and consequently the time of



GAS ENGINE, BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN, ENGLAND.

ignition vary with the load, and this circumstance produces an additional variation of the efficiency with the load.

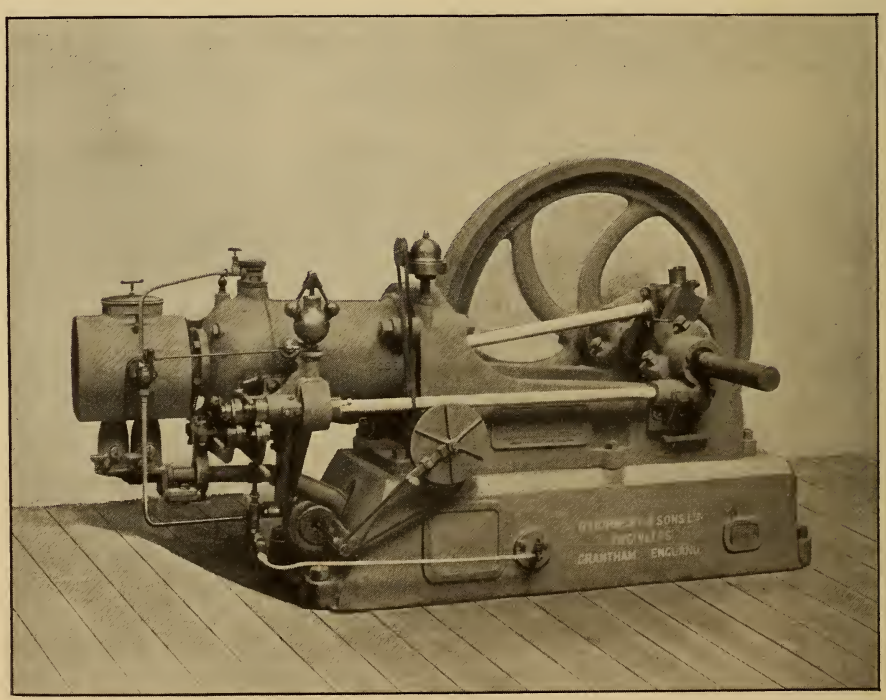
"Oil engines are naturally somewhat more complicated, more expensive, and less convenient than gasoline engines, and unless there be a marked difference in the prices of the two fuels, the latter would seem preferable in most cases."

Concerning oil engines generally, and particularly the already-mentioned Hornsby-Akroyd engine, built in England by Messrs. Richard Hornsby & Sons, of Grantham, and in America by the De La Vergne Refrigerating Machine Co., of New York, Mr. Geo. Richmond has sent us the following :—

"The term oil engine is not infrequently used, in a very loose manner, to describe a variety of engines in connection with which oil is used as a fuel. Steam engines in which steam is generated by liquid fuel are sometimes called oil engines. Gas engines, for which the gas is prepared on the spot by carburetting oil with naphtha or gasoline, are also improperly called oil engines. The term is properly restricted to an engine using a heavy oil from which gas cannot be made without the application of heat.

"As a thermal machine, the oil engine stands about on a par with the gas engine, and both are in this respect very much superior to the steam engine. The gas engine, however, is more costly to run when illuminating gas is used, for the reason that the gas companies charge a very much higher price per thermal unit in the form of gas than the coal merchant does for the same amount in the form of coal. The oil engine is cheaper than the gas engine in running for the reason that the cost per thermal unit in the form of oil is very much less than the cost of the same in illuminating gas.

"The oil engine really dates as far back as the gas engine, but while the latter rapidly reached a practical and



THE HORNSBY-AKROYD OIL ENGINE, BUILT BY MESSRS. R. HORNSBY & SONS, LTD., GRANTHAM, ENGLAND, AND THE DE LA VERGNE REFRIGERATING MACHINE CO., NEW YORK.

economic position, the former has not been put into an acceptable shape until quite recently. While an American can claim the honour of producing the first practical oil engine, its development was left to Europeans. Brayton, in 1872, patented and constructed at Exeter, in the United States, an engine using a heavy oil. A careful trial of a 5 horse-power, American Brayton petroleum engine was made at Glasgow by Mr. Dugald Clerk in 1878. The mean pressure was 30.2 pounds per square inch, diameter of cylinder 8 inches, length of stroke 12 inches. The engine made 201 revolutions per minute, and the consumption of petroleum was 2.16 pounds per indicated horse-power per hour. Much of the total power developed was absorbed in driving the air and petroleum pumps, or, in other words, there was a good deal of friction. During the trial the engine indicated 9.5 horse-power in the motor cylinder. Of this the pump absorbed 4.1 horse-power; therefore, the available horse-power was only 5.4. Only 6 per cent. of the total heat generated was utilized.

"The oil engine of the present day will convert into work 20 per cent. of the heat, and use somewhat less than one pound of oil per indicated horse-power. The chief practical objections to the gas and oil engines is the necessity of igniting the charge. The ingenious arrangement of Otto for transporting a flame into the body of the cylinder was in its day considered a triumph of mechanical skill. The dry heat to which the valve was subjected caused rapid deterioration and required frequent attention. This was followed by what is known as tube ignition, in which a tube is maintained at a red heat by a gas jet. The tube, like an incandescent lamp, has a life-time of a certain number of hours, and is certain to split, sometimes sooner, sometimes later. The third mode of ignition is the electric spark, for which a battery and spark coil must be kept in good running order. This, however, gives less trouble than the contact points themselves within the cylinder, which are liable to become covered with incrustation.

"The two systems of tube and electric ignition have each their advocates who claim great things for them. The fact that there are innumerable patents for improving them would seem to indicate that the difficulties sought to be overcome are not entirely imaginary, of

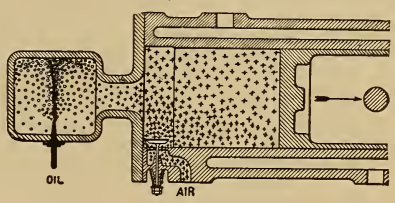


FIG. 1.

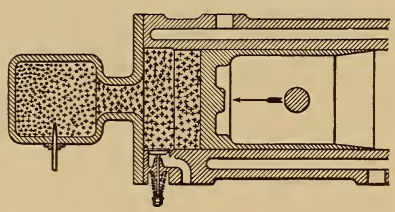


FIG. 2.

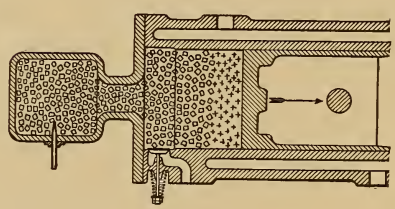


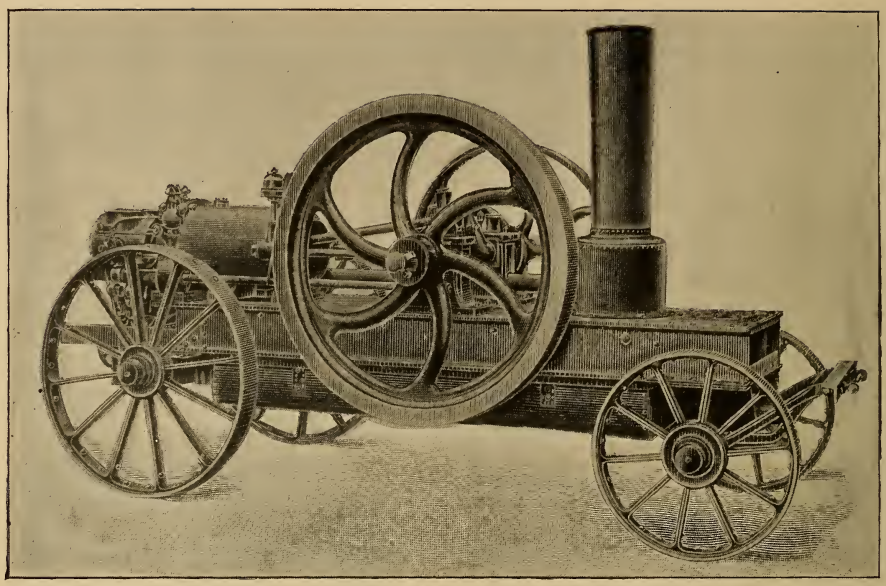
FIG. 3.

HORNSBY-AKROYD ENGINE DIAGRAMS.

+ Indicates pure air. ○ Indicates oil. □ Indicates products of combustion.

which fact no one is better aware than the user of a gas engine. It is worth while recalling the fact that Beau de Rochas, who described, even if he did not use, the four cycle, now known under the name of Otto, recommends that the compression should be carried to a point at which the explosion would be automatic.

"In the Hornsby-Akroyd engine we have the first example of a perfectly successful carrying out of this idea. The automatic explosion is not, in itself, difficult to realize. The real difficulty is in securing this explosion exactly at the moment required. The introduction of valve-motion for timing the explosion



A PORTABLE HORNSBY-AKROYD OIL ENGINE.

would naturally suggest itself, but it must be borne in mind that such valves would be subjected to a temperature considerably above red heat. The manner in which this explosion is obtained in the Hornsby-Akroyd engine is illustrated in Figs. 1, 2 and 3, on the preceding page. The cylinder, it will be seen, is provided with an extension, communicating with the cylinder by a relatively narrow neck. This extension is unjacketed, and forms a retort in which the oil is vapourized. Nothing but oil in the liquid form is injected into the retort, and only air is drawn into the cylinder. The operation, which is perfectly clear from the cuts, is as follows :—

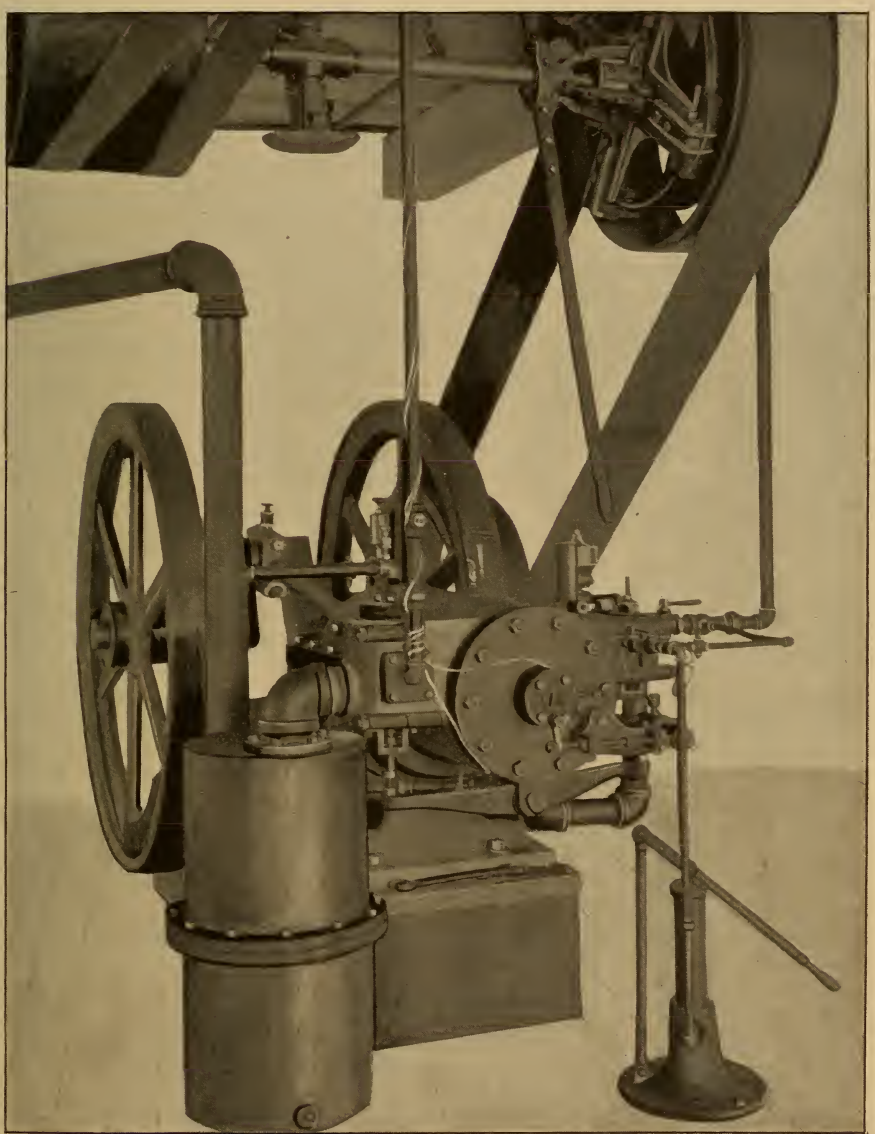
"On the outer stroke of the piston, air is drawn into the cylinder, and oil is injected into the red hot retort. At the end of the stroke we have, therefore, in the retort, oil vapour, which is not explosive, and, in the cylinder, pure air, which is not explosive ; nor is there sufficient leakage from the one to the other to make either of the charges explosive. On the return stroke of the piston, the air is forced from the cylinder through the communicating neck into the retort. For a time the mixture of oil, vapour and air is too rich for explosion, but, as the piston progresses, sufficient air is forced in to make the mixture explosive.

"Fig. 2 shows the mixing process, and Fig. 3, by the conventional marking, indicates that the explosion has taken place, and the cylinder and retort are filled with burned gases. This automatic explosion is found to take place exactly as the piston is making the return stroke.

"It will be noticed that the ignition takes place within the retort, the piston being protected by a layer of pure air. It is not claimed, of course, that these diagrams are exact representations of what actually takes place within the cylinder ; nevertheless, their substantial correctness seems to be indicated by the fact that the piston rings do not become clogged with tarry substance, as is usually the case with this class of engine. This surplus air should ensure complete combustion, and that it is accomplished is evident from careful analysis that have been made.

"At the De La Vergne Refrigerating Machine Company's Works, at New

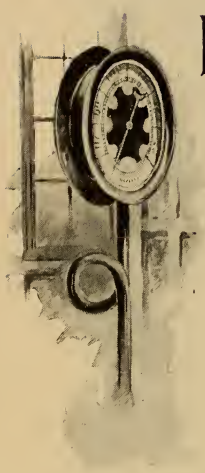
York, a Hornsby-Akroyd oil engine is running some wood working machinery for the pattern shop, and it is interesting to watch the promptness with which the governour adjusts the quantity of oil to the varying power which is taken off. The power will range from the full capacity of the engine to nothing, half-a-dozen times within ten minutes."



A 30 H.-P. ENGINE, BUILT BY THE NEW ERA IRON WORKS, DAYTON, OHIO U. S. A., RUNNING ON NATURAL GAS.

THE RECORDING GAUGE FOR STEAM PRESSURE.

By Charles A. Hague.



FOR many years the writer has been deeply interested from a professional standpoint in the subject forming the title of this article. And, the argument is at least plausible, that if the steam engine indicator, revealing a diagram of the forces within the cylinder, is so necessary to the designing and operating of steam machinery ; if the knowledge obtained from the indicator card has been so potent in bringing the steam engine successively and successfully through its many stages up to its present practical perfection, why should we not be equally well informed as to the conditions and operation of pressures within various kinds of vessels and pipes devoted to the useful employment of all sorts of fluids and gases ?

The fact really is, that it is absolutely necessary to be well informed as to the continuance, regularity and correctness for the purpose, of pressures where pressures are used. The steam engine is a more or less complicated machine, operated by a fluid, and often operating upon a fluid, the cause and effect of the energy used, so to speak, being subject to, and dependent upon, pressure. Could there be any folly greater, when searching and striving for economy in operation, than to remain voluntarily ignorant and in the dark, as to what has been, what is, and what probably will be?

Regularity, that key-stone to the arch, is just as easy of acquirement, and much more satisfactory to live with, than the uncertainty and irregularity too often prevailing in the management of organized effort involved in the uses of pressure and power. The tendency of the times in steam power is towards higher and higher pressures, higher ratios of expansion in engines, and consequently towards more expensive and complicated machinery. The study of the boiler designer to-day is to meet the demands for safety, high pressure and economical service ; and in proportion to the mechanical details involved, the boiler engineer's task is as arduous at least as that of the engine designer.

Aside from the question of fuel economy, the wear and strain upon the boiler by widely varying pressures within short spaces of time, even under the old regime of 70 pounds and under, was a great deal more serious than most people comprehended ; and to-day, with the load up to 150 and 200 pounds per square inch, the steadiness of the pull upon the metal is enhanced immeasurably in importance.

The modern, internally-fired boiler, with its heavy shell, its thickness calculated upon the relation between the elastic and ultimate tensile strength, and the load pressure to be used, is not proportionately as strong as its older and thinner-shelled brother. Materials decrease in strength value, as the thickness increases ; they do not so readily resile, and the liability to permanent distortion of section is greater. It is a very reasonable theory that in cylindrical vessels, when the pressure per square inch approaches the tensile strength limit, adding to the thickness will not increase the strength of the vessel.

Reference to figures will aid the mind in grasping and appreciating the sort of experience a boiler plate goes through,

with a varying pressure. Suppose, for example, that an ordinary, under-fired boiler, 60 inches in diameter, and 16 feet long, with a shell $\frac{5}{16}$ inch thick, is calculated to carry a working pressure of 70 lbs. Then, a variation to 10 pounds below the normal, and to 10 pounds above the normal or, say, down to 60 and up to 80, will make a difference of strain upon the metal of nearly a ton to the square inch of section, and, possibly, within a very short range of time. If by neglect, or carelessness when stopping at night, and banking the fires as many do, the heat of the brick-work, added to that of the smouldering fire, hurriedly left after all the steam outlets are shut off, should conspire to raise the pressure to say 100 pounds, then the variation to which the elasticity of the metal would be exposed, would amount to nearly 4000 pounds per square inch of section.

With the monotorial evidence furnished by a recording pressure gauge chart, an opportunity would be afforded, at least, of calling the attendant to account by warnings that would certainly result in closer watchfulness, and steadier pressure. It is not difficult to learn the art of steady firing, if the fireman has adequate means of knowing just what he is doing. To illustrate this matter of varying pressures upon steam boilers unknown to their owners or managers, the writer will cite a case in point, referring to what may take place in the off hours of the night. In this case suspicions had been aroused that all was not right, and to secure evidence, a recording gauge was attached. The first chart of record of pressure which that boiler indicated showed the following:—

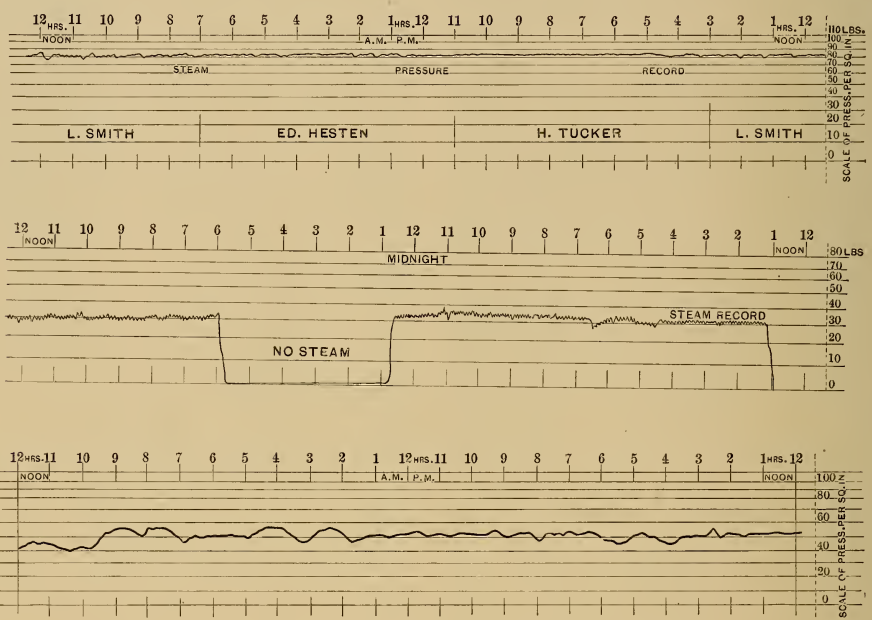
The working pressure was 65 lbs. during the day, and this was supposed to be maintained up until 6 o'clock P. M. But, according to the record, the steam commenced falling at 5.15 P. M. At 6 P. M. the pressure was down to 40 pounds, and the fires were banked as usual for the night, there being no further use for steam until 7.30 the next morning; yet, from some cause, the steam gradually accumulated after 9.30 P. M., and at 1 A. M. it had reached 66 pounds. From this time it remained at about the same pressure until 6.45 A. M., when the fireman came on watch, cleaned and spread his fire, and during his temporary absence the steam ran up to over 120 pounds by 7 o'clock. If that boiler had exploded, the only defense against a "mystery" would have been the recording gauge chart. The safety valve was supposed to have been set to blow off at 70 pounds, but it did not do so; and how many times that boiler had been subjected to such treatment can only be imagined.

With the steam boiler, of course the item of fuel economy is the most tangible one in connection with steady pressure. The gradual but inevitable damage occurring from erratic strains, goes on, but is not appreciated until after considerable time has elapsed, and then the results may be summed up in repairs, in the necessity for a new boiler, or in an explosion. But the practice of obtaining the greatest boiler efficiency, the greatest weight of water evaporated by the heat of the coal consumed, is brought nearest to perfection by means of the knowledge gained in observing how different methods and different fuels have affected the results.

The ordinary steam gauge will, of course, show the pressure at any given moment that one happens to look at it, but who can remember its indications for an hour past, or for a day, or for a week? The knowledge of what he is doing and effecting, will save the fireman much hard labour, and his employer much coal. Imagine an indicator card extending over a month of time; instead of the steam cylinder it is the steam boiler under scrutiny; instead of motion from an engine cross-head, the movement is derived from a clock; but the rising and falling pencil is the same, tracing with unerring certainty the various points to which the steam pressure has risen or fallen.

There are plenty of competent firemen, ready and willing to attend to their duties, but with whom it is an imperative condition that they be thoroughly acquainted with the de-

mands made upon the boilers under their charge. Evidence of the results of a man's efforts, in the shape of a continuous record, and the knowledge that this record is being produced completely outside of his power to manipulate it, can have just one effect out of two; either the fireman must give up his position, or do what is required. And this is not a hardship; for steam boilers proportioned to their work are



SOME CHARACTERISTIC EDSON PRESSURE GAUGE CHARTS.

easily enough attended to by any fireman worthy of the name; and if the boilers are not properly proportioned to their work, the owner should know it as soon as possible for his own interest. The better and more competent the fireman, the more he wants to know what he is doing, and he takes a pride in doing his best when it is known and seen.

Attention to duty, and economy of fuel in firing, are co-incident factors, as each secures the other. In spite of automatic devices for securing uniformity in the performance of steam machinery and steam processes, a steady steam pressure in the boilers is more important than any single item involved. In a flouring or cotton mill, for example, an absolutely uniform steam pressure would enhance the value of the automatic cut-off engine, enable it to control any variation in the load with greater exactness, and produce a closer uniformity in the product. Nearly all, if not quite all, demands upon a steam boiler used for power, may be reduced down to a single proposition, viz.: With a steady steam pressure, equal to the maximum wants under any set of conditions, all demands are confined to the varying quantities of steam.

In electric power and lighting plants, cable plants and others, in which the power is widely varied during different periods of time, but reasonably uniform during any particular period, the raising or lowering of the initial pressure and holding it at the best point will greatly affect the fuel economy for the better. It will sometimes pay better to drop and hold the initial at a lower pressure with a large engine, than to start up a smaller engine. Therefore it follows, that to obtain the most economy in fuel,

close attention to duty, the best performance of machinery, avoidance of explosions, damage and repairs, you must keep your steam pressure as nearly uniform and appropriate as practicable. Wonders can be produced in this line by proper attention and a knowledge of what has been done. If your boilers are not adapted to their work, remedy the difficulty ; but you must find out the trouble first.

If safety valves are supposed to be set at any certain pressure, you can never tell whether they have been tampered with, or whether they failed to blow off when that pressure was exceeded, or how many times a day or night the boilers have been exposed to an excess of pressure. If the steam pressure should run up far above the regular working point, and if a blowing safety valve would betray such a state of things, the moving out of a weight, or the screwing down of a spring, will prevent the blowing even if it does finally ruin the boiler. A good recording gauge will completely expose such practices, and not only that, but it will sound an alarm at the precise moment that the limit of allowed pressure is reached.

Doing the correct thing may be acquired as a habit, and actually less labour is involved in doing it than in doing the wrong thing. Boys from ten to fourteen years of age, deftly and rapidly gauge sheet steel by means of micrometer gauges, and assort the steel for various uses, down as fine as a thousandth of an inch in the thickness variation, simply because they have been taught to acquire the habit of close and quick perception, apparently carrying on their work with freedom and ease. A skilled machinist, accustomed to the use of the micrometer, would undoubtedly take ten times as long to gauge any certain sheet of steel and make sure that he was right, as the quick, easy-moving boy, accustomed to his task, would require.

If the manager of a steam plant knows all about the pressure carried in the boilers at all times,—not only what is being carried, but what has been carried,—and if the engineer and firemen know that this information is upon the official desk, it may be depended upon that half the work of obtaining the best results is done, not so much from fear upon the part of the attendants, as for the reason that they know that an interest, and a very warm one, is taken in what they are doing. Every one knows of the stimulus which comes from the knowledge that one's efforts are important.

If your boilers and machinery are not what they should be, the men are not to blame, but you will be put upon the right road of learning in what respect they are wrong. Leaks, and consequent repairs of boilers and pipes, are almost always caused by abuse, the blame for which is invariably denied in the absence of evidence to locate it. One of the hardest kinds of hard facts in boiler explosions, is that they are mostly caused by over-pressure ; and over-pressure, whether sudden or gradual, is nearly always caused by careless habits in working steam boilers.

A beautiful illustration of this careless and heedless manner of handling boilers is furnished by a case which comes to mind, where, after running, no one knows how many risks, a recording gauge was applied just to settle a dispute between two employees. The chart showed how a night fireman, who was paid for keeping steam at 40 pounds all night, succeeded, and unwarrantably strained the boiler twice before 7 A. M., to the extent of 23 pounds above the point at which the safety-valve was supposed to have been set. The record chart led to the discovery that the safety-valve had been overloaded to 80 pounds, unknown to the superintendent in whose charge the boilers were. But for the recording gauge, these facts might never have been discovered, and a disastrous explosion might have occurred with the so-called safety-valve supposed to be set to blow at 45 pounds.

Some years ago a number of experiments were carried on near New York, with steam boilers under various conditions, and among them

was a case in which a boiler was exploded deliberately and experimentally by over-pressure; but the manner in which the application of different pressures was made, and the results thereof, teach a rather startling lesson in the line of what might happen under careless management. An old steamboat boiler had been removed, and finally turned over to the experimentors for the good of the engineering profession. This boiler had been, when last in use, tested by hydrostatic pressure up to 59 pounds; had been allowed, by the steam boiler inspectors of the district, to carry a working pressure of 30 pounds, and, soon after being removed, was subjected to an experiment which resulted in a violent explosion, completely demolishing the boiler.

The records commenced with a steam pressure of 29½ pounds, and in thirteen minutes the boiler exploded with terrific violence at a pressure of 53½ pounds, or 5½ pounds below the hydrostatic test pressure. The rise of steam pressure during the experiment was fairly uniform, and when 50 pounds was reached, some of the stay bolts parted in the welds, the crow-feet remaining in place; then, a few minutes later, quite contrary to the accepted belief as to old boilers gradually giving out with little or no violence, the entire boiler exploded like an immense bomb shell, leaving nothing at the location but a mass of mutilated tubes. If that boiler had been in useful service, and subject to neglect at various times, with the pressure going to no one knows where, at some time or other, a few minutes' absence of the fireman or engineer, coupled with an overloaded safety-valve, would have caused the most destructive sort of a boiler explosion, with the usual mysterious accompaniments. Many will perhaps remember the terrible "Westfield" ferry-boat explosion in New York Harbor a number of years ago, under circumstances which might well have been parallel with those of the experiments above mentioned. The "Westfield" had nothing but ordinary pressure gauges attached to the boiler, and in spite of the evidence attempted to be taken at the time, no one really knew what the pressure was at the time of the disaster, nor how many times a safe pressure had been exceeded in the regular practice of the boat.

In mills and factories running night and day 144 hours per week, as many do, to say nothing of those running constantly for months, the recording steam gauge brings about comparisons of different attendants on duty at the different hours, which are bound to result in a great deal better and more economical average than could possibly be obtained without it. The writer has records from a steamship, showing, that when the vessel was being propelled by the same engineers, under the same conditions, in four watches, while the firemen were in three watches, a difference of thirty per cent. in consumption of fuel existed between the most wasteful and the most economical watches. Doubtless, there are many other cases equally bad, or worse, on shore, and on shipboard too, for that matter. It must be obvious, therefore, that the greatest importance should be attached to the recording of steam pressure, so that those in authority may read at a glance the very great difference between attention and inattention, between knowledge and ignorance. In fact, apparent knowledge, and real ignorance, may be brought much nearer together by appropriate use of the record.

The engine, or whatever apparatus uses the steam, is responsible for the steam received, but the boiler and the fireman are responsible for the amount of coal required in producing the steam; and it has been shown to be possible for the fireman to get away with a third more coal than is necessary to produce the power required, simply by departing from the practice of correct firing. The fuel should be burned down to a proper point so that the furnaces will not gradually fill up with unconsumed coal. The first thing generally done by a green fireman is to gradually allow the furnaces to fill up, working oftener and harder than necessary himself. If a number, say, four or six doors, are to

be fired into, each should be fired separately with an interval between, regulating the damper to correspond, and keeping the water at the same level at all times in the boiler.

Firing is much easier when properly understood and manipulated. Some men will fill a furnace full of coal, so as to have more time to walk around; soon, up goes the steam pressure, because more heat is generated than is wanted at the time; then, the feed water is turned on, and the water level is run up to keep the steam down; the safety valve blows, or it may not blow; the draught is checked, the fires smoulder, then, large quantities of carbonic-oxide gas go up the chimney, which is simply an escape of unconsumed fuel, not wanted at the moment. After a while the fires burn too low, and down goes the steam pressure, helped down, perhaps, by a furnace full of fresh coal; the feed water then is turned off, and the water level run down to help the steam up.

Imagine the final effects upon a boiler used in such a manner, and also imagine how such an outrage can be perfectly exposed by a constant unerring record of what takes place every minute of the day and night. Let the fireman understand that his own grading depends upon himself as established by his record. You must pay him what he is worth; that is beyond your control and his; you may vary the wages, but you will also vary the fireman, and you will come nearer to getting an adequate return for your money, with a good fireman than with a bad one. The recording gauge is the arbitrator, and both sides of the case will be brought to account by it. When the chart shows a greater pressure than it has been determined upon to carry, something is wrong that can be remedied; when the chart shows considerable periods of steam pressure below an economical point, money is going to waste that can be saved by a knowledge of the facts.

The practical value of this steam record, then, consists in compelling the fireman to give reasonably close attention to firing, to exercise care and intelligence, and to maintain that uniformity of water level in the boilers, without which the best results cannot be obtained. Although absolute uniformity of steam pressure can not be had, still the margin of fluctuations can be held within close limits, as is attested every day.

It can readily be seen how soon an instrument of comparatively small cost, which will compel a maximum of care and attention, or at least reasonable care and attention, in the use of fuel, can be made to pay for itself over and over again. Even where the consumption is but a few tons per day this is true. How absolutely essential then must be such an apparatus in large and important plants where the amount of fuel is expressed by many figures, and particularly on steam vessels which have to carry, at the expense of freight storage, the coal they use or waste.

When the recording pressure gauge was originally introduced, some twenty-five years ago, it was primarily for the purpose of effecting economy, and, incidentally, safety in the operation of steam boilers in connection with steam engines, both afloat and ashore; but since that time innumerable other uses of steam have come to be benefited, and have given other arguments and illustrations of the value of a recording gauge, so that wherever steam is used its records are necessary for the best results. If a building was to be heated, especially a building filled with tenants, many a dispute, and sometimes a law suit, has been avoided by the chart of record, indicating that at any certain hour the required steam pressure had been faithfully maintained. A product is to be turned out in some branch of manufacturing requiring a uniform steam heat; or a chemical change is to be effected; or whatever purpose for which the heat of steam is to be used; the steam must be used according to certain instructions, and often the pressure that gains the best results can be determined only by experiments, and the data relating to temperature for

these can be based accurately upon these records.

As far as the generation of steam at the boiler is concerned, it has been abundantly proven, and is beginning to be pretty generally conceded, that a recording gauge always insures the means for constant and careful attention upon the part of the fireman, and gives the engineer or superintendent in charge a detailed, written record of the operations of the boiler room throughout every hour of the day and night, the result being the maintaining of much steadier steam, with, of course, the accruing benefits in the economical use of fuel, economy in wear of boilers, in use of grates, and, in fact, economy in all that pertains to the production of steam.

So much, then, for the making of the steam. But the benefits of steam pressure records do not stop at the point of retaining a proper relation between the quantity of fuel burned and the amount of steam made, conceding that the utmost economy has been attained by careful, intelligent firing, assisted by a knowledge of what is being accomplished. This very regularity of pressure, which has been so potent in economizing the production, is of equal, or greater, value in controlling the consumption of the steam by the engine, especially in these days of high pressure and multiple expansion.

The old-fashioned single-cylinder, slide-valve engine, controlled by a throttling governour, with steam cut-off by the lap of the main valve, at three-quarters or seven-eights stroke, could not have its rate of steam consumption materially affected by the rise or fall of steam pressure, for the reason that such an engine works, even at its best, under the worst economical conditions as a steam engine. A variation of pressure was met by the governour opening the regulating valve more or less, but not affecting any ratio of expansion, because none existed. The plain slide-valve engine was displaced by the automatic cut-off, single-cylinder engine, but it was soon learned, although the latter effected a very considerable saving of steam over the former, and gave better regulation of speed, that, for the best results, the automatic engine needed a pretty uniform steam pressure under a fairly steady load to enable it to keep its range of cut-off within certain prescribed limits. Of course, its point of cut-off, or steam pressure could be varied considerably, but not without greater proportionate loss of economy than was suffered by its older rival.

Then, the compound, automatic engine entered the field, emphasizing still more the desirability of practically uniform steam pressure. The triple and quadruple expansion engines, now becoming quite common, still further draw attention to the item of steady pressure for best results. With the latter class of engines, in electric power, and lighting stations, where the heavy loads, and the moderate loads, at different stated periods, have clearly defined limits, the very essence of economy can be obtained by bringing the initial steam pressure to a point determined by actual working conditions as the best for any particular period. There the pressure record would be invaluable, and the cost of a recording gauge might be saved in a week or two.

In flouring mills, cotton mills, and other industries where the demands for power are extremely uniform and with the compound, the triple, and the quadruple engines now in vogue, of from 1200 to 2000 horse-power, the close approach to absolutely steady steam pressure possible is a very desirable item indeed. Threads can be spun finer and woven closer with steadier power; the weight of coal per barrel of flour is now-a-days figured to three places of decimals. It has been estimated by an eminent technical professor that a cube of coal, small enough to just pass through a finger ring, will generate enough steam to transport a ton of freight a mile with the modern ocean steamer. The modern saw-mill owner who, not long ago, was supposed to be thankful for any kind of effort able to turn a buzz saw, now figures upon the

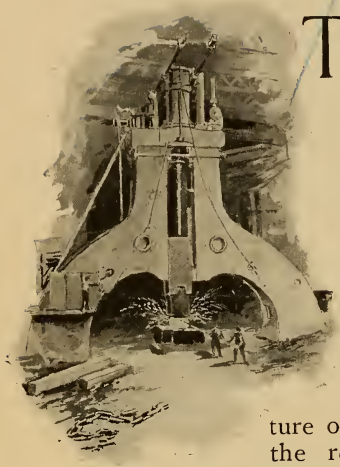
waste or saving of lumber involved in different widths of saw kerfs ; and the entire saw mill practice in the great Northwest, at least, of the United States, has been so completely changed since ten years ago, that there is as much difference between then and now, in saw mills, as between the slide-valve and the automatic engine. All these changes have been towards refinement and steadiness in power and machinery, economy of lumber, uniformity in product.

The development of the genius called by the name of Steam, in all his might and power, has been long and gradual; and, now, that he has about reached the zenith of his position in the world, he is beginning to discover that he has helped very materially in the development of a rival, probably a near relative. The electrical age has fairly dawned, but its moving spirit is still helpless, and depends in practical life upon some other form of tangible energy, chiefly that of steam ; and, until its fetters are discovered and broken, so that some form of chemical action shall enable the electrical current to spring full-fledged into active life, we shall be constrained to continue upon good terms with our old and well-tried friend, steam. And as long as this is so, we must keep close watch upon the giant's pulse ; to keep him as nearly as possible within that happy medium which gives the best commercial results.

The throwing away of the latent heat, either in the non-condensed exhaust, or the overflow from the air pumps, presents a barrier at present insurmountable to any great advance upon the line of steam engine economy; but for all that, steam will hold its place, and will need to be recorded, until some sort of missing link is discovered between the production of the two acids, one of which represents combustion, and the other of which will produce the electric current. So far, we can better afford to throw away ninety per cent. of the heat of the coal, than to utilize ninety per cent. of the effect of the zinc. This is not scientific, but simply commercial; and means that, so far, the difference in the market prices is too great between the two minerals.

COMMERCIAL TESTING OF MATERIALS.

By William O. Webber.



THE testing and inspection of materials for railroads and manufacturers is one of great importance and also is quite generally misunderstood. A great many think that such a system involves a very great expense, as well as a great expenditure of time, and that the results, when obtained, are largely theoretical. This is not necessarily so, and, in a great measure, depends on the man in immediate charge of this work, as well as on the general policy to be pursued.

There are two classes of this kind of work, which may be designated, for want of better terms, as "absolute" and "commercial," the former being that sort of testing and analysis which would be undertaken by an expert chemist or testing laboratory to determine the absolute value of any sample submitted to them; and the latter, or "commercial," being the determining of the value of a number of samples as compared with a predetermined standard, or the detection of sufficient foreign substances as to prove adulteration.

Perhaps a good example of this difference might be shown by the consideration of the testing and inspection of a lot of white lead paint ground in oil. The "commercial" procedure would be to bore holes in about ten kegs out of a lot of one hundred, and abstract about an ounce of the contents of each. These are then thoroughly united in the laboratory, and an average sample, weighing one gramme, is taken in a caserole and treated with ether, which liberates the boiled linseed oil. This is then absorbed by strips of blotting paper whose previous weights are known, the ether is allowed to evaporate, and the second weighing of the strips then gives the weight of the oil.

The lead, being now free from oil, is dried to obtain the moisture, by weighing before and after, and a gramme, as before, of the dry white lead is put into a platinum boat in a glass combustion tube. This tube is connected as shown in the annexed sketch, Fig. 1, *a* being the platinum boat containing the white lead; *b*, an alcohol lamp; *c*, *c'*, *c''*, U-tubes containing sulphuric acid and broken pumice stone to prevent any moisture in the air from entering the tube during combustion; *d*, is a caustic potash bulb to absorb the carbonic acid gas liberated by the combustion; and *e* is a U-tube of pyro-gallic acid in caustic potash to absorb any oxygen that may be liberated and driven over. The water bottles *f* and *g* serve to produce a suction and pressure of air so as to induce the gases to all flow in the direction of the arrow. This apparatus can be kept hanging up, already assembled on the under side of the reagent shelf on the paint analysis table, and a combustion for a period of twenty minutes is all that is necessary to determine the value of the lead sample.

The air is dried out of the tubes, they are weighed, the combustion takes place, the tubes are weighed again, the excess of weight in the potash bulb being carbonic acid gas, of which there should be, theoretically, 44 parts,—practically about 40. The weight of the tube *c''* represents moisture liberated

by the combustion and the remaining oxide of lead (223 parts) is found in the platinum boat. The amount of oxygen in the pyro-tube should be small and is merely to check results. Now, it would not escape detection to adulterate white lead with anything except some material

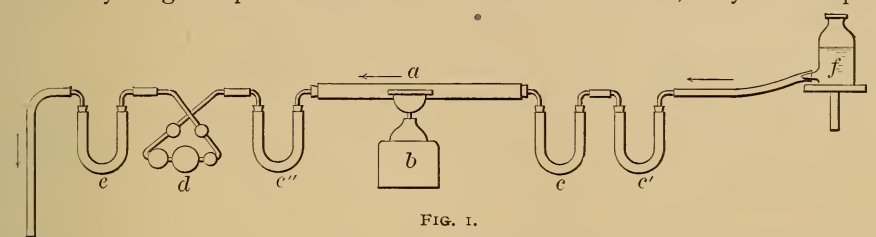


FIG. 1.

nearly white in color, of about the same specific gravity as lead, and which must, of course, to be "profitable," cost less than white lead.

The substances that come under these requirements are very limited, sulphate of baryta, or barytes, being that one whose price and gravity more nearly offer a "profit" as an adulterant. But it would not "pay" to adulterate with barytes even, unless about 30 per cent. were added, so that, if by our combustion we find anywhere from 35 to 40 parts of carbonic acid gas, we can assume our lead to be pure, and the amount of gas found will give a relative value to the sample as compared with what we have obtained from other samples, and a standard.

Another practical point in the consideration of white lead as a paint is whether it has been properly desilverized. All lead contains silver in greater or less quantities. We find that by painting small slabs of white wood with a sample of lead in which we know the percentage of silver, we can obtain a "color test" scheme similar to that employed in determing the carbon in steels and quite as accurate. The presence of silver in lead gives it a "pink tinge." The whole time consumed in investigating this sample as just outlined need not exceed an hour and a half. A dozen samples of different lots of lead can be investigated and reported on in a forenoon.

The absolute process, to obtain the absolute percentages of carbonic acid, oxygen, metallic lead, silver, etc., would require two or three days, and yet, would be of no greater value for inspection and manufacturing purposes. The silver test alone, if by the wet process would require dissolving, precipitation, filtering and drying, all taking time; and if by fire analysis, as practiced to obtain known samples for the standards required, there would be necessary combustion in a sealed crucible, and the cupellation of the resultant button, to obtain the "bead" of silver. Either of these processes would require fully a day's time, and must be done one by one.

Oil inspection can be done in the same way, a known amount of oil being run on a testing machine, until the temperature is raised from 80° to 200° F., and the length of time and total number of revolutions are noted of two consecutive tests which must again be compared with similar tests of a "standard" winter strained lard oil (especially prepared), and of which similar tests may be made each day, immediately preceding or following the tests of the oils under consideration. This enables the correction of all such conditions as temperature and humidity of the atmosphere. The gravity, flash, burning and freezing tests may be made in the usual way.

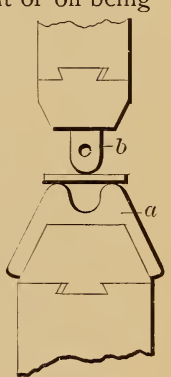


FIG. 2.

As regards the inspection and testing of boiler plate, each sheet has a "coupon" left attached when sheared at the mill, and this is numbered to correspond with the sheet, with one-half

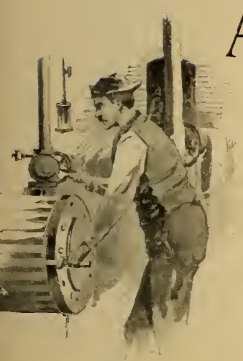
inch steel figures. The coupon is cut into a tensile sample, 9 inches long, and one each for cold, hot and chilled bending, 5 inches long. The 9-inch tensile sample is reduced in the centre to 4 inches between the shoulders, and all percentages of elongation are considered with a 4-inch standard. The bending samples have their edges dressed to remove the wire edge caused by the shears, and are first bent under a small steam hammer, used as a press, by being laid over a shoe placed on the lower die, formed like *a* in the sketch, Fig. 2, and the handled former *b* is pressed down on the test strip until it assumes the shape of a letter U. After all have been so treated the die and former are removed and the pieces shut down flat by light taps of the hammer.

The writer's first "tensile" tester was the wheel press in the car shops where the push of the ram was converted into a pull by the interposition of suitable mechanism. The cylinder of the press was fitted with a gauge, very carefully and accurately made, which read to 10 lbs., had a maximum capacity of 40,000 lbs., and was provided with a tell-tale needle which was left at the highest point reached by the gauge finger. A table based on this reading and the area of the ram gave us our tensile strains. This table, of course, had to be calibrated for the friction of the ram, which was found to be quite nearly constant. We were afterwards provided, first, with a 300,000 lbs. Riehlé machine, 60 ft. long, on which we tested bridge bars up to 40 ft. in length, and later on with a 100,000 lbs. Fairbanks automatic machine. No attempts were made to ascertain the elastic limit on boiler plate, as the other tests were deemed sufficient, but on bridge bars this was done and the record was obtained in a very simple manner without using micrometer extension screws and electric contacts, all of which take time. We had simply a rod of steel and brass which was clamped fast to one end of the rod under test, being set into prick punch marks, and the other end of this rod was provided with a pointer in a trammel head. On the rod being tested and clamped to it directly under this pointer, was a holder carrying a brass plate. As each successive increment of load was put on the bar a scratch was made on this brass plate, and the load noted as added and scratched to correspond. As soon as the elastic limit was passed, the scale beam would refuse to stay poised and the scratches made before reaching the elastic limit would be found to be exactly even distances apart; as soon as that limit was passed, however, a correspondingly greater distance would occur between the lines. The method was very simple, quickly carried out, and sufficiently accurate for all practical purposes. Care had to be taken in adjusting the gauge rod in the first place, and it had to be supported on rollers and free from any strains and its own weight, but these details once overcome the rest was easy.

Our original axle drop was the drop weight used in the foundry for breaking scrap, but this was found to be too dangerous and cumbersome, and a regular drop was therefore constructed.

STEAM ENGINES OF TO-DAY.

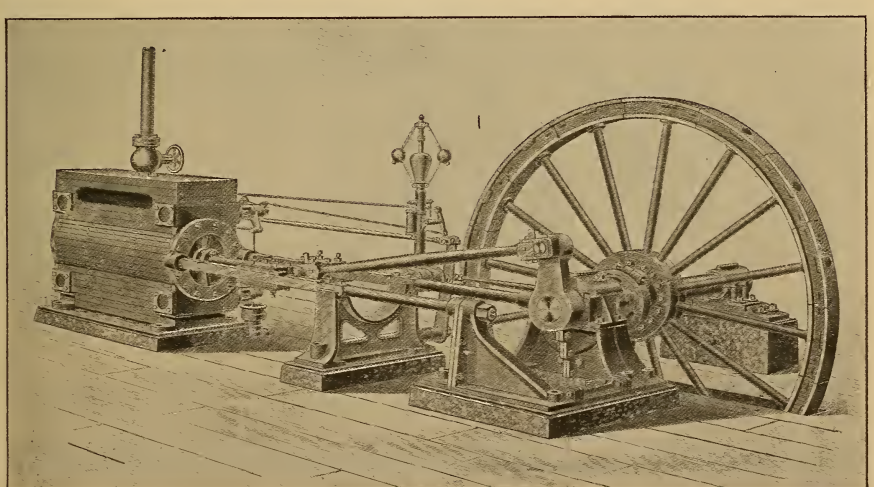
By George L. Clark.



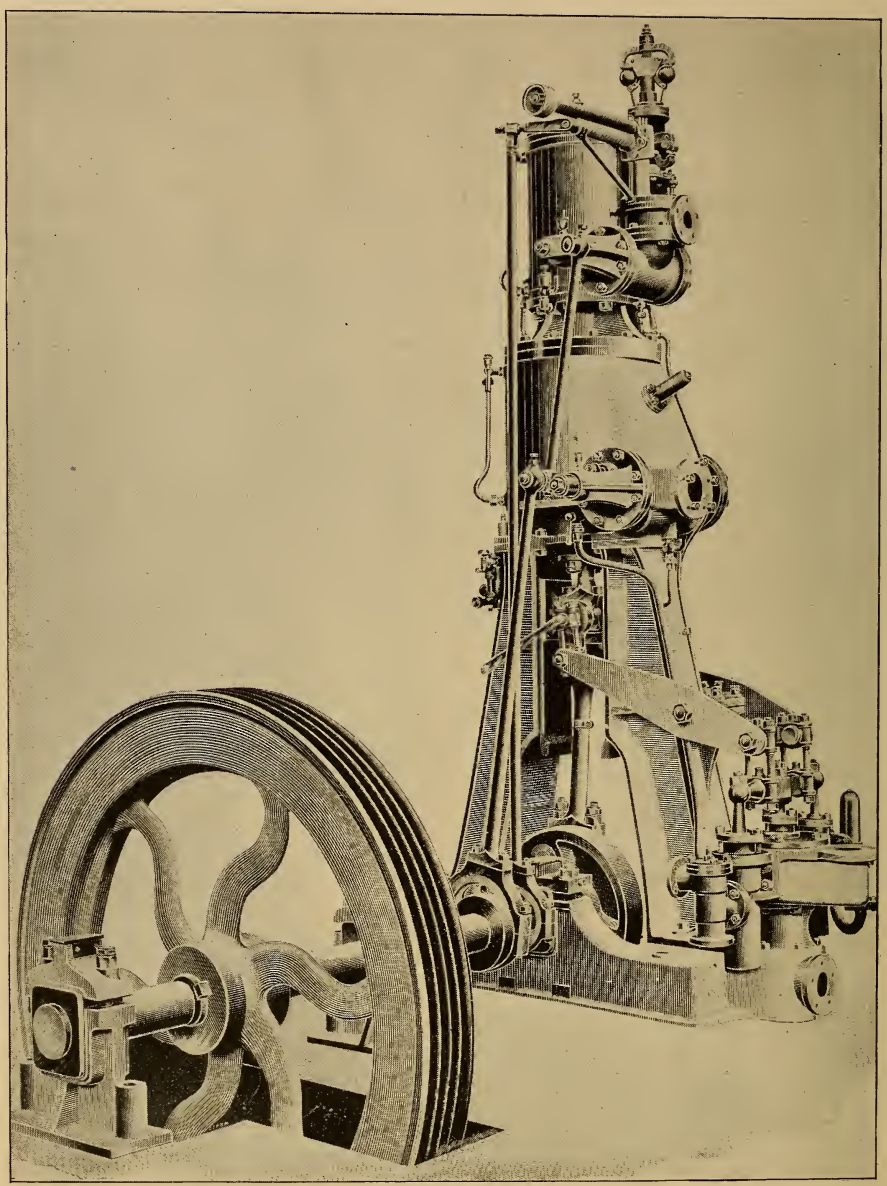
A COMPARISON of steam engine designs, be they old or new, is often full of interest and instruction, illustrating not only, in some cases, a species of distinct evolution in that particular field of engineering practice, but showing, too, expedients that have been, and may again be, adopted with measurable success in working out power problems. Standard engines, taken from a builder's stock, and obtainable almost immediately on demand, will not always satisfy a user's requirements. There are special cases which must have special designs, and a few of these have been selected for illustration here, together with several others which, though now articles of regular manufacture, depart sufficiently from general practice to merit notice.

One of the latest outcomes of English practice, for example, is the vertical, tandem-compound engine shown on the next page, which, to American engineers, at least, will prove all the more striking from the fact that it is intended for sawmill work, having been built for the mills of Messrs. Vint Brothers, of Bradford, England. For the following particulars of the engine, as well as for the illustration, the compiler is indebted to *Engineering*, of London. A single Proell valve is used, which is designed to act merely as a cut-off valve, the distribution of the steam being effected by cylindrical valves of the Corliss type.

The distributing valves are, in each case, fitted at the lower ends of the cylinders, and are worked by one eccentric, the arrangement being such that



SECTIONAL CORLISS ENGINE, BUILT BY THE FULTON ENGINEERING AND SHIPBUILDING WORKS, SAN FRANCISCO, CAL., U. S. A.



VERTICAL TANDEM-COMPOUND ENGINE WITH PROELL EXPANSION GEAR, BUILT BY MESSRS. WESTGARTH, ENGLISH & CO., MIDDLESBOROUGH, ENGLAND.

nearly straight lead for the rods is obtained. The lowest level of the edge of the exhaust port is lower than the bottom of the cylinder, both in the case of the high-pressure and the low-pressure cylinders, and there is thus no risk of water accumulating beneath the pistons and causing damage. The Proell valve and gear is fitted above the high-pressure distributing valve, and is worked by a separate eccentric which raises the valve in time for the commencement of each stroke, and maintains it open till the release gear, worked

by the governour, comes into operation and lets the valve fall again, thus cutting off the steam. Comparatively little lap is thus required on the distributing valve.

The arrangement is very compact, and, owing to the adoption of the cylindrical Corliss valves, the clearance spaces are much less than is usual with independent cut-off valves of the ordinary slide pattern. The exhaust from the high-pressure cylinder passes to the steam chest of the low-pressure cylinder through a cast-iron pipe. The valve for this cylinder is also of the Corliss pattern, but has a passage through it, by means of which the necessary range of oscillation is reduced. In practice, the arrangement adopted is stated to have proved very efficient, there being a difference of only two per cent. in the speed of the engine at full load and at no load.

The two cylinders, it will be seen, are mounted direct, one above the other, without the intervention of a distance piece. The low-pressure cylinder cover is, however, made rather deeper than usual, to afford room for the metallic stuffing box shown, and to reduce the clearance in the high-pressure cylinder. The packing referred to consists of a number of white metal split rings of angular section, which surround the rod and are kept up to their work by spiral springs of phosphor bronze placed above them. These springs are placed over long studs or pins of phosphor bronze, as shown, which serve to maintain them in place. The principal dimensions of the engine are: Diameter of high-pressure cylinder, 9½ inches; diameter of low-pressure cylinder, 16 inches; stroke 16 inches. The speed is 110 revolutions per minute. The engine was built by Messrs. Westgarth, English & Co., of Middlesborough, England. Mr. Herman Kuhne, of London, is the English agent for the Proell patents.

Another vertical engine, but of the triple-expansion type, and intended for coupling direct to a dynamo, is shown on the next page, this illustration, too, having been reproduced from *Engineering*. The engine is of the marine type, open-fronted, with all the parts easily accessible. The cylinders are 8¾, 14 and 20 inches in diameter, and the stroke is 9 inches. The designed speed is 310 revolutions per minute, at which, with 150 pounds initial steam pressure, the indicated horse-power is 120. Being designed for such an unusually high speed, special attention has been paid to the bearings. These are of gun metal, with a large area, and every attention has been given to lubrication, which can be easily effected, even when the engine is running at full speed. The question of balancing, also has been carefully considered, so that the running is very smooth and quiet. A shaft governour controls the speed, acting directly on the slide valve. The cylinders all are jacketed.

An engine of radically different design and purpose is the sectional engine shown on the opening page, and which, as its name implies, is made in pieces, light enough to be carried by mules or horses to stations of difficult access, in mountain districts, for mining work, for example. The heaviest piece, except the crank shaft, comes within the weight limit of 300 pounds.

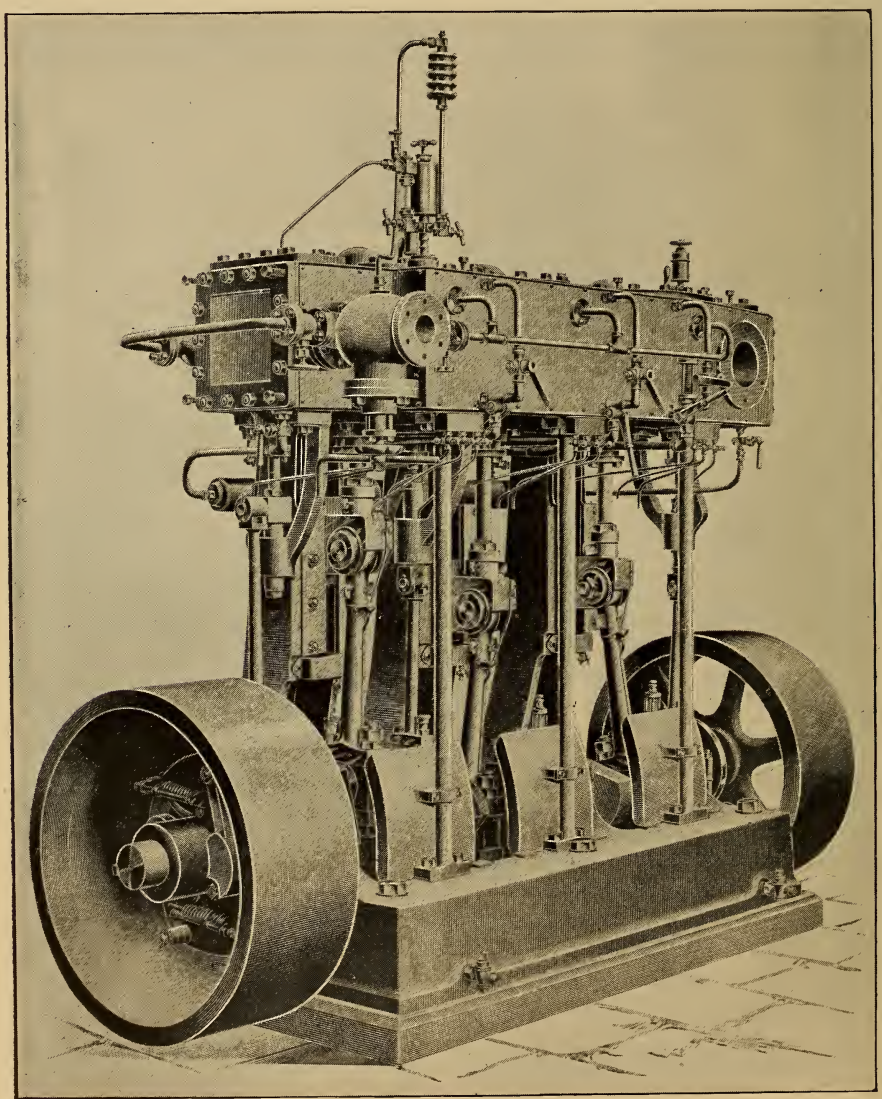
The two main conditions governing the design of an engine like this one, are sub-division and reduction of weight, with careful attention to strains and the disposition and strength of the material entering into the make-up. The chances are that the duty will be severe. When one buys an engine to be transported over mountain passes on mule-back the heating surface and cylinder capacity are reduced to their least limit, which means heavy duty. The present case proves this. The engine, 18″ x 36″, when started, ran eight months continuously, day and night, with a detention of eight hours, or one hour each month, a record, probably, without precedent.

The division of the main pedestal and the fly-wheel can be followed out in the illustration, but the cylinder, which is in nine or more pieces, is covered in, so that nothing can be seen except that the contour is the same as for a stand-

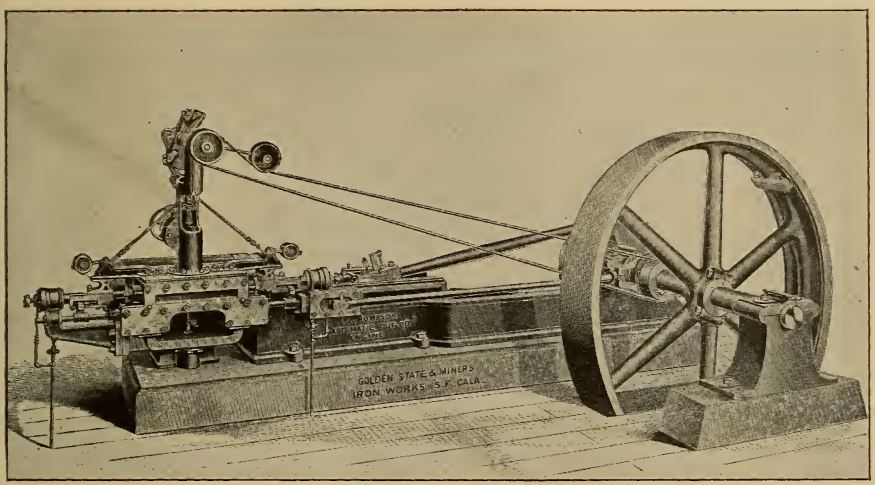
ard engine of the kind. The cylinder is divided transversely into five parts, fitted together and then bored. The valve boxes are bolted on, and the base flanges of the exhaust chamber are detachable.

The central stand, supporting the guide bars, which are also tie rods, is in a single piece less than 300 pounds in weight. The main pedestal is divided, as seen, into four parts, and has a central chamber under the main bearing, which, by this reinforcement, is greatly reduced in cross-section and weight.

The nave of the fly-wheel is in eight parts, consisting of four segments on each side of the spokes. The latter are round bars of wrought iron, three inches in diameter each fastened by a



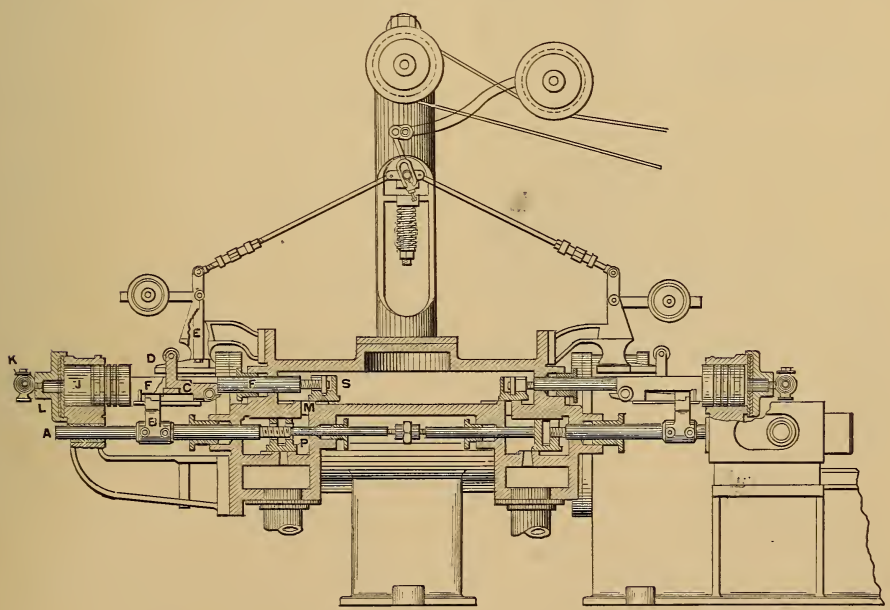
VERTICAL TRIPLE-EXPANSION ENGINE, BUILT BY MESSRS. ROBEY & CO., LIMITED, LINCOLN, ENGLAND.



SLIDE-VALVE CORLISS ENGINE, BUILT BY THE GOLDEN STATE AND MINERS' IRON WORKS, SAN FRANCISCO, CAL., U. S. A.

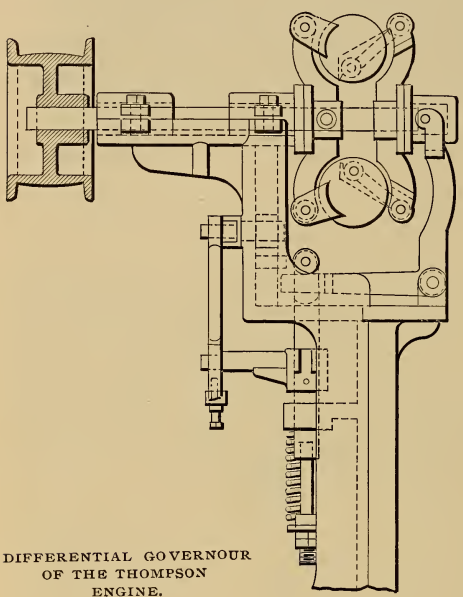
countersunk nut in the fly-wheel rim, which is in sixteen sections or segments, as shown, joined by links and keys.

Not the least interesting of the multitude of Corliss designs that have sprung into existence is the Thompson flat slide-valve Corliss engine shown, in perspective and detail, on this and the next pages, and built by the Golden State and Miners' Iron Works, of San Francisco, Cal., U. S. A. One of these engines was exhibited at the Chicago World's Fair in 1893, and these furnished power for some of the miscellaneous machinery shown in operation in Machinery Hall.



SECTION SHOWING VALVE DETAILS OF THE THOMPSON ENGINE ABOVE.

There are two steam and two exhaust valves, and, as shown in the sectional view on page 515, the valve rod A is continued from the eccentric rod through the two exhaust chambers, and the valves P are fastened to this rod and are moved regularly by the motion of the eccentric. An arm or hand, B, with a steel face, is fastened to the exhaust rod at each end, just outside the chamber. The steam valve



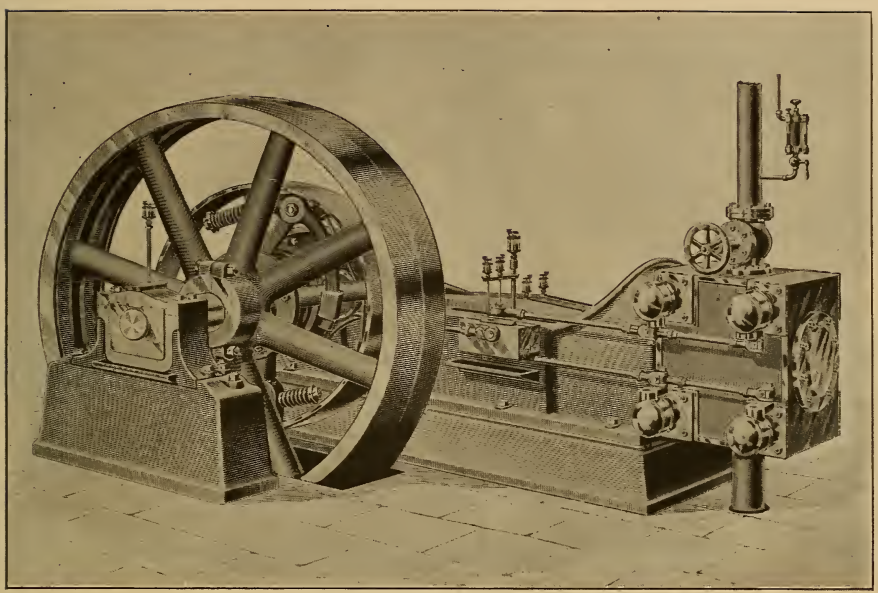
DIFFERENTIAL GOVERNOUR OF THE THOMPSON ENGINE.

rods F, which pass in through the end of the steam chamber, and to which the steam valves S are fastened, have each a knee trigger, C, pivoted in them, and the steel faces of the hand on the exhaust rod, coming in contact, alternately, with the steel faces of the knee triggers, push each valve, in turn, off its port M until steam enough enters to do the work of that stroke. Then the wedge D, adjusted by the governour, raises the trigger out of contact with the arm on the exhaust rod, and the steam valve is instantly thrown over its port by the pressure of the steam within the steam chamber.

The steam valve rods have each a dash pot, J, at the end, with air cushion, to arrest the momentum when the valve and rod are closed. The wedge D, being set so as to trip the trigger when the engine is running with a normal load, at normal speed and with normal steam pressure, every change of load or of speed or of steam pressure is instantly followed by a change of the position of the wedge, backward or forward, to correspond. Should there come an added load, or a decrease of steam pressure, the governour draws the wedge back, allowing the valve to move that much farther off the port and more steam to enter, and *vice versa*. All four valves are moved by one eccentric, and with but one joint between the eccentric and the valves, being at the sliding block that transmits the motion of the eccentric to the exhaust rod A. In the case of a tandem-compound, the second cylinder being built on the same plan, the additional movement is effected by the same eccentric without any additional joint.

The action of the governour will be understood from the two detail views. The engine, according to the builder's claim, can be run at as high a speed as 150 revolutions per minute. Cylinders, equipped with this form of valve gear, can also be substituted on any engine where the old cylinders are removable, thus securing all the advantages of the design and saving the cost of the balance of the engine. On the western coast of the United States this form of engine appears to have met with quite some favor, and is in successful operation in a number of large mills and electric light and power stations.

Another form of four-valve engine, the latest of recent engine designs, is what has become known as the Atlas cycloidal engine, of which several illustrations are given on the following pages. The valves of this engine have flat surfaces and reciprocating motion, with a multitude of ports, so arranged as to give wide opening with the least practicable travel. The valve gear is simple, direct and positive, independent of releasing parts, dash pots, springs or gravity, and opposing no limit to speed. The valve seats are cylindrical in shape, turned to fit the bored-out valve cham-

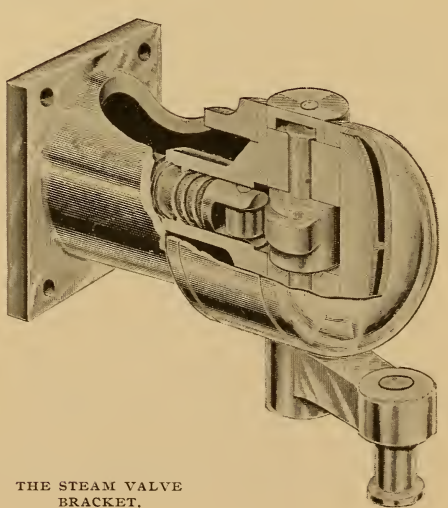


CYCLOIDAL ENGINE, BUILT BY THE ATLAS ENGINE WORKS, INDIANAPOLIS, IND., U. S. A.

bers, and split lengthwise, obliquely to their axes. The part which forms the valve seat proper having been inserted in the chamber, the other part is forced in over it, thus wedging down and securing it without any other fastening. It is thus easily removed for inspection or refitting by simply driving back the binding piece. The operating faces are double, flat and inclined to each other at a sharp angle.

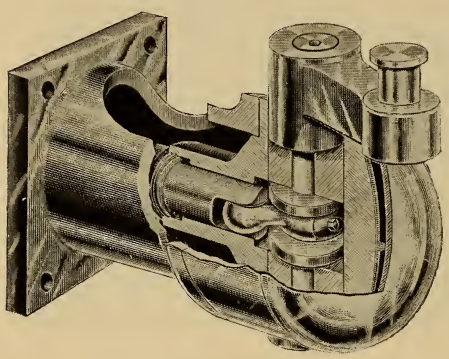
The valve is triangular or trough-shaped in section, which enables it to be made very thin and light while retaining ample stiffness to prevent buckling by heat and pressure. This shape also gives it such a bearing on the seat as to prevent danger of "cocking." Valve and seat have a large number of ports operating on the grid-iron principle. These ports, in all sizes of the engine built, are only a quarter of an inch wide and half an inch apart, attaining the required area by their length and number. The valve when closed has one-eighth of an inch lap around each port, and gives a full opening with but three-eighths of an inch of movement. The valve being very light, and the movement very small, removes all difficulties arising from inertia. The proportion of port area adopted is one-sixth the area of the cylinder, and the ports, being very short and direct, admit the steam without perceptible loss of pressure at the highest practicable speed.

The mechanism for operating the steam valves is peculiar, and gives the distinguishing name adopted for the



THE STEAM VALVE BRACKET.

engine. The valve stem extends outward through the valve bracket, and is provided at its outer end with a hardened steel roller, running on a hardened steel pin. Supported in adjustable bearings in the bracket is a short oscillating shaft, on which is mounted a cycloidal cam, against which the valve stem roller bears. On the valve stem,



THE EXHAUST VALVE BRACKET.

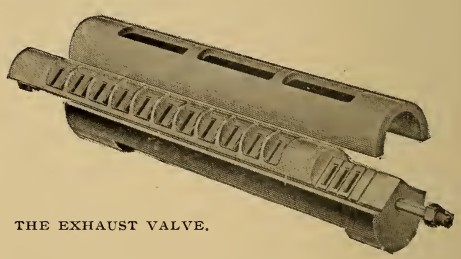
working in a cylindrical opening in the base of the bracket, is a small piston, acted on by the pressure of the steam in the valve chamber to keep the roller in constant contact with the cycloid. The latter, receiving an oscillating motion from a variable eccentric under the control of a speed governour on the engine main shaft, gives the valve a quick reciprocating motion to open and close it, allowing a period of repose in the open and closed positions. The motion is variable in time by the governour, so as to give the requisite admission and cut-off of steam to adapt the amount to the load without variation of speed. The action of the cycloid and roller is smooth and easy. The cycloid has four acting surfaces which may be brought successively into operation should change of shape occur from wearing, and the roller and pin are small parts, easily renewable. The part of the bracket containing this mechanism is closed and forms an oil chamber, so that the wearing parts are constantly immersed in lubricating material.

The exhaust valves are very similar in construction and operation to the steam valves, except that the angles of the valve and seat are reversed in position. This is done to diminish port clearance, which it reduces to a very small amount. The mechanism for

THE STEAM VALVE.

operating the exhaust valves differs but little from that provided for the steam valves. A small eccentric and yoke are substituted for the cycloid, and the arrangement is such as to afford a quick opening and closing movement, and to permit the valve to remain nearly motionless during its closed period. The exhaust valve stems work through simple stuffing boxes. The same provision is made for lubrication of working parts as for the steam valves.

In the tandem-compound design of this engine, the cylinders are overhung and connected by a distance piece with a supporting foot. The steam passes from



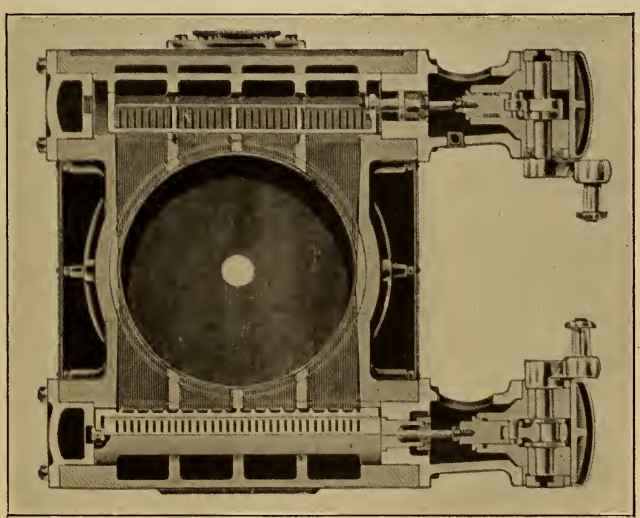
THE EXHAUST VALVE.

the high to the low-pressure cylinder through a passage in the distance piece, which is protected by lagging from loss through radiation. This arrangement avoids the use of unsightly connecting pipes. Each cylinder is provided with separate lining of metal, readily replaceable if required. In the high-pressure cylinder the space surrounding this lining is utilized as a steam jacket; in the low-pressure cylinder the corresponding space is left empty for an in-

sulating space, as experience is against the economy of steam jacketing the low-pressure cylinder. The governour which controls the action of the steam valves is a modification of the shaft governour long supplied by the manufacturers on their older styles of automatic engines.

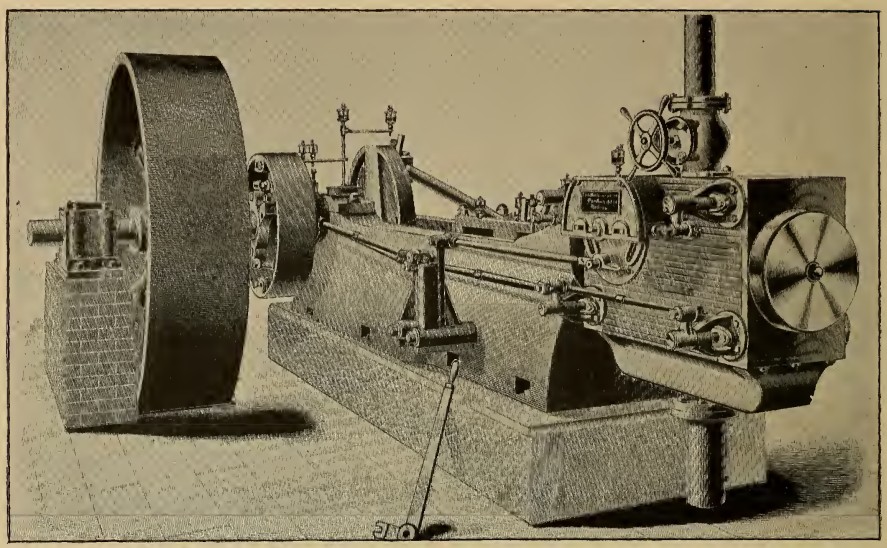
Among the many engines which may be classed among those of the Corliss type, though having very distinct characteristics of their own, is that designed by Mr. W. H. von Mengeringhausen. The steam valves are multi-ported, and slots at each side which serve as guides to the flat ends of the roller pins as the rollers are moved toward or away from the centre of the wrist-plate when the latter oscillates. These rollers are carried in the forked ends of the valve rods, and a spring at each end of the frame keeps them always in contact with the outer or wearing surface of the wrist-plate grooves.

The operation of the valve gear is as follows :—As the main shaft revolves, the eccentric, through a rocker arm, imparts an oscillating motion to the



SECTION THROUGH THE VALVE CHAMBERS OF THE ATLAS CYCLOIDAL ENGINE.

the valve motion is without the conventional release gear and dash-pots. All connections are positive, so that the engine can be run at a relatively high rotative speed. As shown, both in the general view of the engine and in the diagram on the next page, the oscillating wrist-plate has two symmetrical grooves or slots of irregular outline. Each of these has two circular portions, of different radii, yet concentric with the axis of oscillation. These concentric portions are connected by a short curve which is provided with removable hardened steel bearing pieces to take the wear of the rollers working in the grooves. The wrist-plate frame has wrist-plate, causing the grooves to swing through arcs of circles. While, however, the rollers are in either of the end portions of the grooves, the swing of the wrist-plate will not impart motion to the valves, since those portions, as already stated, are concentric with the axis of oscillation ; but when the rollers are passing from one portion to the other, as from the part of larger radius to that of smaller, or *vice versa*, the curved surfaces of the bearing pieces give a rapid motion to the roller, causing the valve quickly to open to full port, or to close with equal quickness at the desired point of cut-off. There are two eccentrics, that for the exhaust

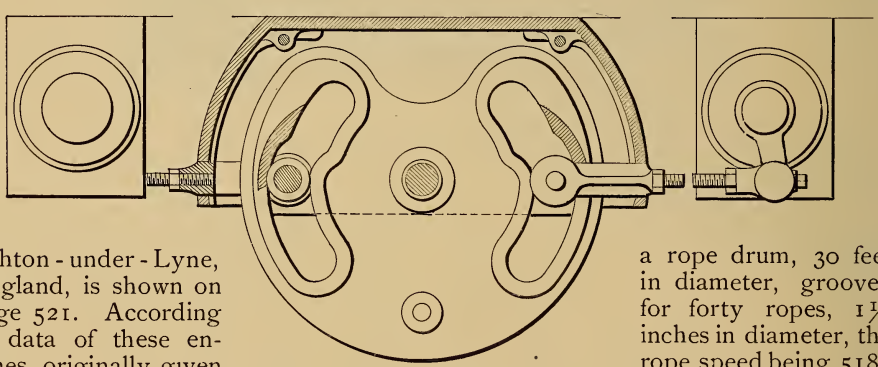


THE VON MENGERINGHAUSEN ENGINE, BUILT BY THE A. B FARQUHAR CO., LTD., YORK, PA., U. S. A.

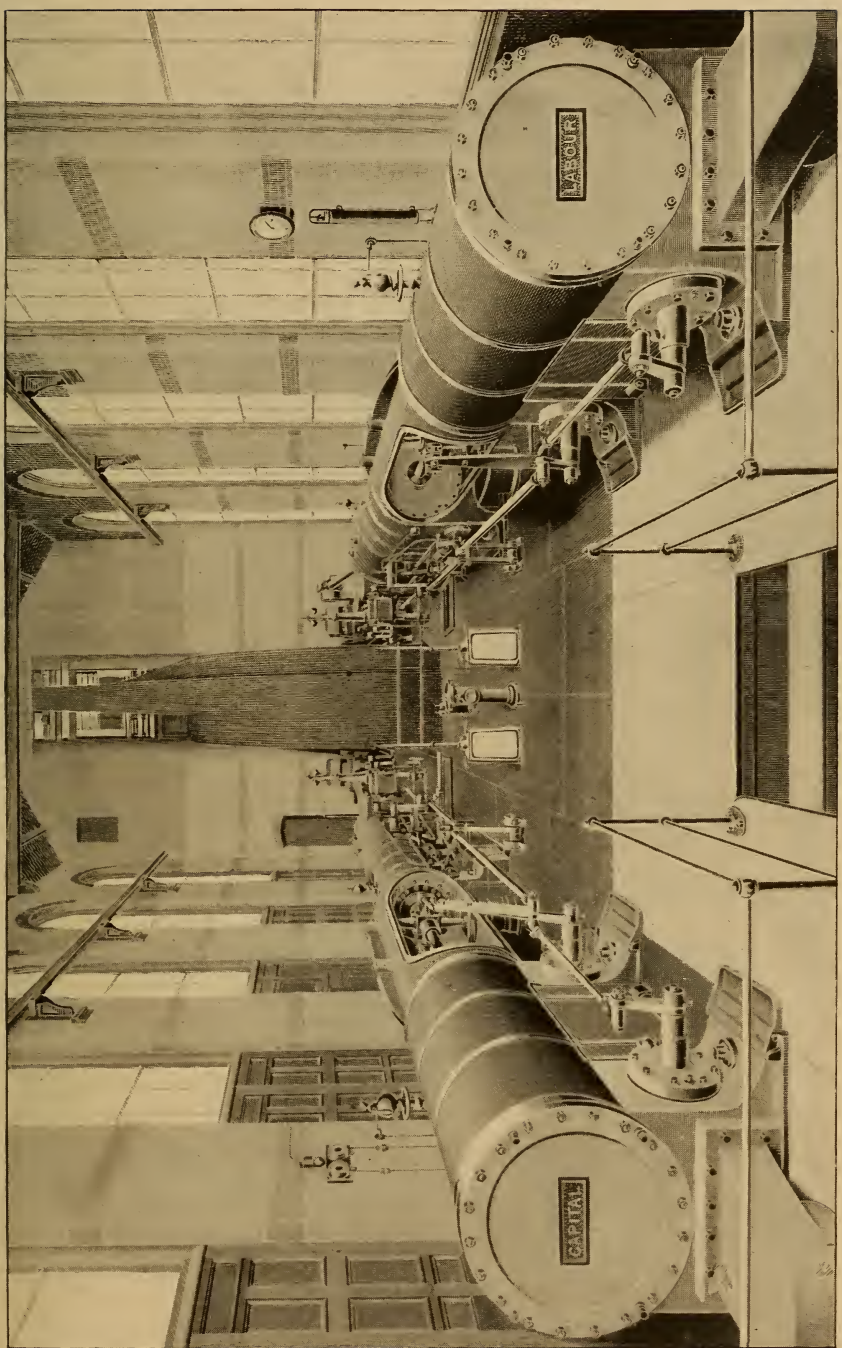
valve being fixed to the shaft close to the main bearing, while the other is connected with the governour.

A pair of horizontal triple-expansion mill engines, built by Messrs. Daniel Adamson & Co., of Dukinfield, for the Minerva Cotton Spinning Company, at Ashton-under-Lyne, England, is shown on page 521. According to data of these engines, originally given in *Engineering*, there are two cylinders, arranged tandem fashion on each side of the main driving drum, the high and one low-pressure cylinder driving one crank, and the intermediate and remaining low-pressure cylinder, the other crank. The high-pressure cylinder is 22 inches and the intermediate cylinder 36 inches in diameter, while the two low-pressure cylinders are each 40 inches in diameter, the stroke of all being 6 feet. Running at 55 revolutions per minute with 160 lbs. steam pressure, the engines develop 1500 horse-power.

Power is taken from the engines by a rope drum, 30 feet in diameter, grooved for forty ropes, 1½ inches in diameter, the rope speed being 5185 feet per minute. The drum is built up in segments, with loose arms and boss. The arms are socketed into the boss and bolted to the rim segments. The total finished weight of the drum is 65 tons. It has an internal barring rack, cast inside the rim, the barring being effected, when required, by one of the builder's automatic safety barring en-



VALVE GEAR DETAIL OF THE VON MENGERINGHAUSEN ENGINE.



1500 HORSE-POWER TRIPLE-EXPANSION MILL ENGINES, BUILT BY MESSRS. DANIEL ADAMSON & CO., DUKINFIELD, ENGLAND.

gines. The general design of the engines themselves is of the Corliss type. Between the two cylinders on each side are distance pieces with slides for crossheads which are used as couplings for the high and low-pressure cylinder piston rods and also as supports for the rods. The distance pieces are of such inside diameter as to permit the easy removal of the cylinder covers and pistons without disconnecting any other parts of the engine. Advantage is further taken of the coupling crossheads just mentioned for driving the air pumps, which are fixed immediately underneath the distance pieces.

The two low-pressure cylinders are fixed upon separate cast-iron foundation frames which are securely bolted to the foundations, but the cylinders themselves can slide freely on these frames, and thus accommodate themselves to the expansion and contraction of the engines. The high-pressure and the intermediate cylinders are each fitted with automatic expansion gear, each being controlled by a separate and independent governour, positively driven by gearing. The two low-pressure cylinders have circular semi-rotating valves, one at each end of the cylinder. The expansion gear is of the Wheelock type.

The arrangement, mentioned, of having the high-pressure and intermediate cylinders automatically controlled by independent governours, affords two practically complete engines. The main stop valve is fitted also with an electric stop motion, arranged to close the valve automatically in case of accident in any department of the mill.

THE REDHEFFER PERPETUAL MOTION MACHINE.

By Professor Coleman Sellers, E. D.

DR. HENRY MORTON, in his interesting paper on "Engineering Fallacies" in the January number of this magazine, in which he gives a description of Redheffer's perpetual motion machine, makes no allusion to Robert Fulton's final exposure of the fraud. In Scharf & Westcott's "History of Philadelphia" there is an account of this piece of mechanism and brief mention is made of its afterwards having been exposed by Fulton. I happen to have a copy of "The Life of Robert Fulton, by his friend, Cadwallader D. Colden, read before the Literary and Philosophical Society of New York," published by Kirk & Mergein, 22 Wall street, New York, in 1817, and some reference to this may be acceptable to those who are interested in the subject.

The author, while treating the subject of submarine guns and other harbor defenses proposed by Fulton, showing the interest taken by Mr. Thomas Jefferson in these inventions, goes on to say that before pursuing the subject, the practical knowledge Fulton had acquired in mechanics and the quickness of his apprehension can be illustrated by the part he played in regard to Redheffer, who had deluded so many people by his perpetual motion. He mentions that "many men of ingenuity, learning and science who had seen the machine came out as zealous advocates of it, while others afraid to admit that he had made a discovery which violated what were believed to be the established laws of nature, appeared afraid also to deny what the incessant motion of his wheels and weights seemed to prove. They supposed that Redheffer had discovered some means of developing a hidden power which, though it might not be able to give perpetual motion to the machine, would at all events keep it going for a period which they did not pretend to determine."

No description is given of the Redheffer machine, but the author states that one of these machines began its career in the city of New York in 1813, that is, four years before the publication of his volume, which certainly appeared while the events were likely to be remembered, and goes on to state: –

"Mr. Fulton was a perfect unbeliever in Redheffer's discovery, and although hundreds were daily paying their dollar to see the wonder, Mr. Fulton could not be prevailed upon for some time to follow the crowd. After a few days, however, he was induced by some of his friends to visit the machine, which was exhibited in an isolated house in the suburbs of the city.

"In a very short time after Mr. Fulton had entered the room in which it was exhibited he exclaimed, 'Why, this is a crank motion.' His ear enabled him to distinguish that the machine was moved by a crank, which always gives an unequal power, and therefore an unequal velocity in the course of each revolution, and a nice and practiced ear may perceive that the sound is not uniform. If the machine had been kept in motion by what was its ostensible moving power, it must have had an equable rotary motion, and the sound would have always been the same.

"After some little conversation with the showman, Mr. Fulton did not hesitate to declare that the machine was an imposition, and to tell the gentleman (Redheffer) that he was an impostor. Notwithstanding the anger and bluster which these charges excited he assured the company that the thing was a cheat and that if they would support him in

the attempt he would detect it at the risk of paying any penalty if he failed.

"Having obtained the assent of all who were present, he began knocking away some very thin little pieces of lath, which appeared to be no part of the machinery, but to go from the frame of the machine to the wall of the room, merely to keep the corner posts of the machine steady. It was found that a catgut string was led through one of these laths and the frame of the machine to the head of the upright shaft of a principal wheel, that the catgut was conducted through the wall and along the floors of the second story to a back cock-loft, at a distance of a number of yards from the room which contained the machine, and there was found the moving power. This was a poor old wretch with an immense beard and all the appearance of having suffered a long imprisonment, who, when they broke in upon him was unconscious of what had happened below, and who, while he was seated on a stool gnawing a crust, was with one hand turning a crank. The proprietor of the perpetual motion soon disappeared. The mob demolished his machine, the destruction of which immediately put a stop to that which had been, for so long a time, and to so much profit, exhibited in Philadelphia."

In Scharf & Westcott's "History of Philadelphia," the reproduction of the advertising circular of Redheffer to attract attention to his machine shows that the admission charge was $5 for men, while women were admitted gratis during the exhibition in Philadelphia.

In continuing the subject of the model of Redheffer's perpetual motion machine, so well described by Dr. Morton, it may be well to note that I have every reason to believe that two models were made by Mr. Isaiah Lukens, the one figured and described by Dr. Henry Morton as in the possession of the Franklin Institute of the State of Pennsylvania, and one of later construction, built for the Philadelphia Museum collection. This was catalogued not as "Redheffer's," but as "Isaiah Lukens' Perpetual Motion."

I have no information regarding this latter model other than that afforded me by one of my brothers, now nearly ninety years of age, who, when much younger, explained to me in what particulars it differed from the model now exisiting. The museum model was probably lost with that part of the Peale collection which was destroyed by fire in the building at the corner of Seventh and Chestnut streets, Philadelphia, where it was then stored. The late Mr. Coleman Sellers, the writer's father, who died in 1834, was intimate with Isaiah Lukens, and the changes in the museum model, it is said, were made at his suggestion, and, doubtless, under his supervision, in the interest of his father-in-law, Mr. Peale, for whom it was built.

In the Franklin Institute model, the clockwork that gives motion to the wheel is hidden in the base-board of the machine and probably has not been seen by anybody for very many years. It is wound up by turning one of the four knobs on the columns that support the frame of the machine. The power is conveyed to the main wheel, upon which the inclined planes and wagons are supported, by means of a vertical shaft, with a spur wheel gearing into a second wheel upon the main shaft, these two wheels being entirely concealed in a brass yoke, beneath which yoke there is room to pass a strip of glass about as wide as an ordinary microscope slide. A similar glass slide seems to support the lower step of the driven shaft. These pieces of glass can be removed, and apparently the vertical shaft of the main wheel and the shaft carrying the driven pinion rest upon this glass, being steadied only by the yoke, but, in point of fact, the glass has nothing whatever to do with the mechanism.

In the museum model this part of the apparatus was entirely different. The spindle of the machine passed into the baseboard, apparently surrounded by a glass bushing and resting upon a glass plate at the bottom. The step had the appearance of a stationary glass support for the step of the upright which was of polished steel. When the clock-

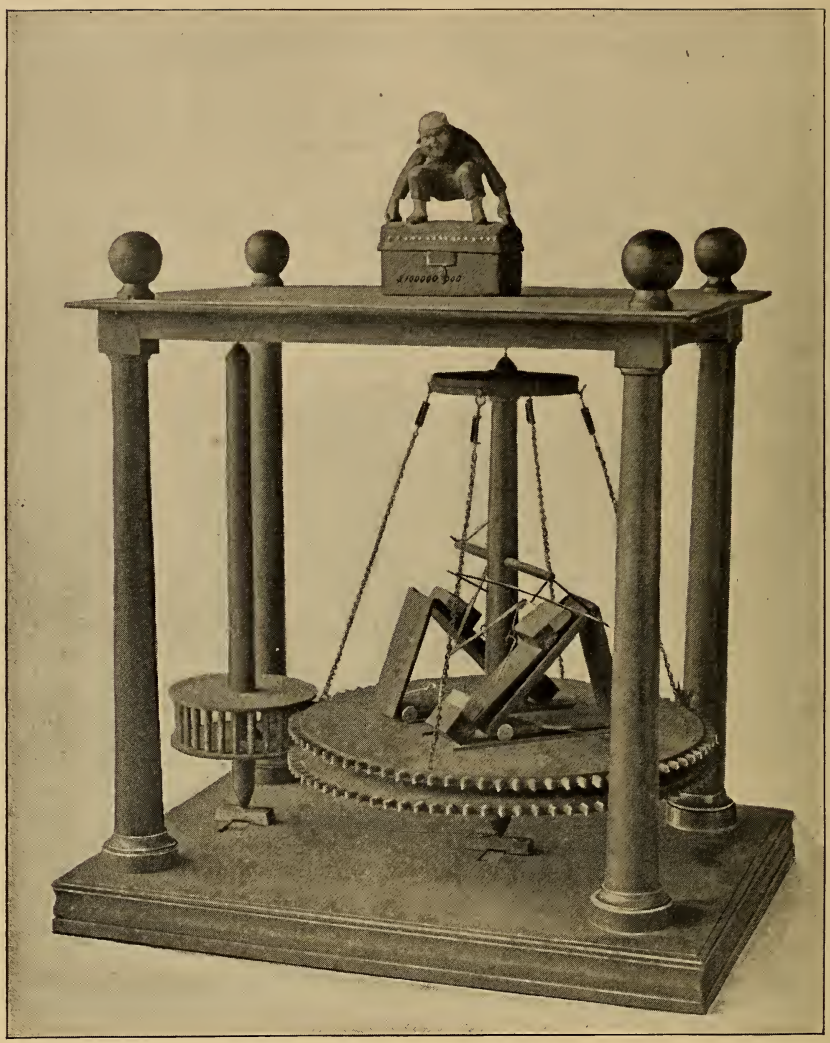
work was in operation this glass plate was continually revolving, but it required the weights to be placed upon the carriages on the inclined plane to give sufficient adhesion to cause the wheel to revolve. The steel step was not ground perfectly true on the base, but touched on one side only, in such a manner as to make it act as a crank through the slight adhesion to that part of the glass which was roughened enough to give it the adhesion it required. The museum model could be taken apart and all the separate parts laid upon the table and examined critically by any curious person, and when reassembled and the weights put on, the motion would begin, at first slowly, and at last acquiring the full rate that was capable of being accomplished by the clockwork. It was this peculiarity of taking the machine apart and putting it together again that gave the opportunity to wind up the clockwork, as in securing the knobs on the posts to fasten it together, this motion served to wind up the clockwork for the time being.

It is to be regretted that Mr. Colden's description of the destruction of the Redheffer machine is not a little more explicit. Mr. Colden merely says that the catgut string led through one of these laths and the frame of the machine to the upright shaft of "a principal wheel." There were but two wheels in the device, that is, the large one and a lantern pinion on an upright shaft, into which it geared. In the Philadelphia exhibition this shaft ostensibly gave motion to a grindstone or some other working machine, which, in reality, gave motion to the perpetual motion machine itself. That this was the case was indicated by the way the pins in the lantern pinion on the upright shaft pressed upon or marked the plugs or teeth in the periphery of the large wheel, so that insufficient as the description given in "The Life of Fulton" is, yet it substantially agrees with the supposed conditions that were explained by those who disbelieved in the invention in Philadelphia.

About twenty years ago I had a long talk with a Mr. Levering, who, at the time of Redheffer's exhibition of the machine in Germantown, resided not far from his place and was then a man grown. He gave me a very graphic description of the machine as he had seen it, but assured me that among those gentlemen appointed by the State Legislature to inspect the device there were none probably who had the slightest belief in its being a new development, but all counted it a fraud. It is not at all likely that such men as Robert Patterson, Oliver Evans, one of the most noted engineers of the day, and Lewis Wermwag, all members of this committee, should have been for a moment deceived by any exhibition that was at variance with the laws of nature upon which we base our knowledge of mechanics.

From such descriptions as I have been able to gather from those who saw the machine in Philadelphia, it must have been operated in a manner different from the New York exhibit. In Philadelphia a grindstone was operated by the machine, apparently, and there seemed to be power enough developed to permit steel instruments to be sharpened upon this grindstone. One shaft of the grindstone approached suspiciously near to the partition of the room and was hidden by some pieces of wood that had no apparent connection with the machine. It was believed at that time that an elongation of the grindstone extended into an adjoining room and a man was there concealed who operated the device by turning this crank to give motion to the grindstone, and the grindstone motion was conveyed by its attachment to the machine itself.

The day after the Philadelphia City Council passed a resolution appointing a committee to ascertain whether a machine on the principle of Mr. Redheffer's invention might be made capable of raising to a sufficient height a sufficient quantity of water for the use of the citizens of Philadelphia, there appeared an article in the *Aurora* signed "Rittenhouse." The writer thereof stated that the machine had



MODEL OF THE REDHEFFER PERPETUAL MOTION MACHINE.

never been seen in actual operation for more than half a day, and avowed his firm belief that it was a deception. It was after this that Mr. Lukens made the model now owned by the Franklin Institute. The controversy between those who believed in this perpetual motion and its opponents was conducted in the pages of the *Aurora*, the files of which are, doubtless, accessible in the libraries.

In the very good illustration of Redheffer's perpetual motion model, which appeared in the January, 1895, number of CASSIER'S MAGAZINE,* there is shown on top of the model a figure of a man on top of a trunk, apparently taking hold of the straps connected with the handles of the trunk on each end. This, of course, had nothing to do with the original model, but was presented to the Franklin Institute by Mr. Thomas Shaw, of Philadelphia, and was placed upon the

*The illustration of the Redheffer machine, which accompanied Dr. Morton's original paper, is reprinted here for the sake of possibly added interest.—THE EDITOR.

Redheffer model as an excellent illustration of attempts to accomplish perpetual motion, the idea being that this figure is really holding down the trunk which he is endeavoring to lift from the floor. This has a parallel in the old analogue of perpetual motion, viz: Trying to lift one's self from the floor by hauling on one's boot straps.

My chief object in adding my testimony to that already furnished by Dr. Morton is to express my firm belief in his assumption that we must rely upon our knowledge of conservation of energy and the correlation of forces to disprove the principle of all so-called perpetual motion machines, the list of which does not end with those mentioned by him, but is still, from time to time, extended. A distinguished engineer of London advises me that he has read with interest Dr. Morton's paper on "Engineering Fallacies," and apropos thereof, says that there had only recently been presented to him for examination a so-called perpetual motion machine upon which many thousand pounds had already been expended.

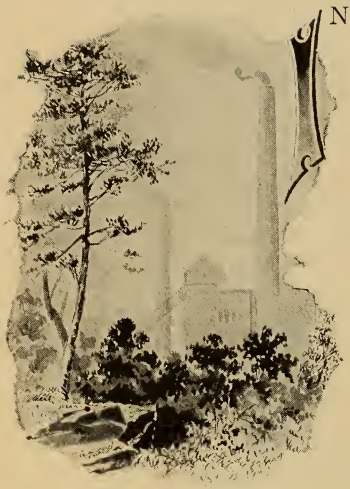
Closely allied to these claims for the production of perpetual motion are the class of exhibitions which have been profitable to their inventors by organizing companies through active promotors, upon evidence, for instance, that a few drops of water can produce a pressure of 10,000 lbs. per square inch, as though this was tantamount to the performance of a useful amount of work.

Again, there is the line of pseudo-experimentation, based upon the oft-repeated assertion that harmony of sound can set up such motion as to produce large mechanical effects, such as the rotation of machines, or act with explosive power in guns. All such devices may properly be considered as perpetual motion machines, for in such cases the power manifested is much greater than that required for its initiation, and it must follow that the machine, after supplying itself with such initiatory excitement will have much surplus energy left over for useful purposes, if the facts are as stated. In fact, such surplus energy has been looked for by the promoters, but has not yet so far revealed itself as to render feasible the construction of machines of practical use and commercial value.

The means to carry on exhibitions of such reputed inventions are obtained from widely scattered sources. Generally those who have furnished the capital are not interested in the exposure of the frauds, or do not realize that advantage is being taken of their credulity, while those who are not pecuniarily interested are afforded no opportunity to prove the correctness of their assumption as to the fraudulent nature of the display. The floating of such schemes is much too easy, as the ordinary tendency of the human mind is to freely believe that remarkable results may be obtained from modern scientific methods. This faith leads many to venture at least small investments in the hope that large returns will be realized, and I fear this tendency will continue to exist as long as faith without reason is dominant in many minds.

THE BARRING ENGINE.

By W. H. Booth.



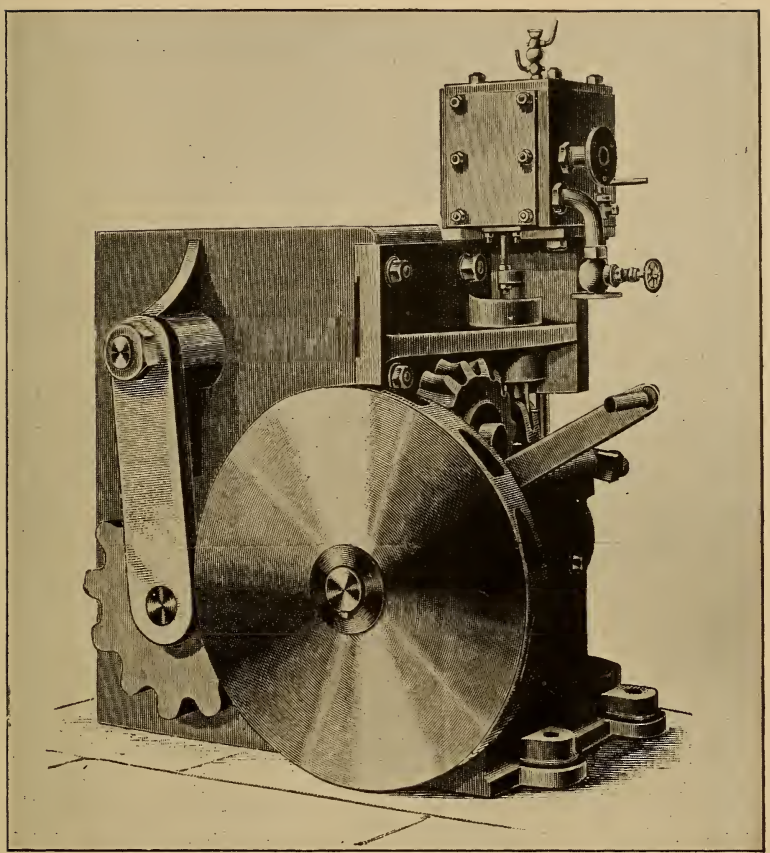
IN the early days of factory engines the single beam engine was the sole motive power, and it frequently happened that the crank would stop upon the dead point. For this, it was necessary to find a means of starting the engine, and for such engines, as then employed, it was quite sufficient to place a rack upon the wall behind the fly-wheel and use a crowbar, bearing upon the arms of the wheel, and with its point in the rack.

When toothed rims took the place of the fly-wheel, there were usually a pair of engines and these would start from any position, and the bar became unnecessary, except for occasions when repairs were in progress and a slight movement of the engine was needed. For that purpose a rest was fixed on the floor, close up to the spur-wheel, and the teeth of this were used as the point of application of the bar.

With the advent of ropes for main driving, and the progressive increase in the size and power of engines, the power of one man to turn them became insufficient, especially where, as often happened, many of the machine bands had been left on the working pulley, for many of the workers will always insist upon getting the maximum of revolutions out of the machines, and are thus apt to leave belts in position. The frequent employment of the single engine again, which is found to give perfectly steady turning effort with the aid of the large fly wheel rims now employed, demands some means of turning the crank off the dead point, and the demand was strengthened still more by the necessity of something to turn even the double engine when new ropes were being put on.

All these considerations led to the employment of barring engines, as they have been termed. These are small, two-cylinder engines, so arranged as to gear with an internal toothed rim, carried inside one edge of the large rope pulley. When the small engine revolves, it drives this large pulley round through the medium of a pinion, which gears in the above internal spur, and of a worm gear, the worm being on the shaft of the small engine. If steam be turned into the main engines while the barring engine is at work and the large pulley overruns the little engine, the effect is simply to push the pinion out of gear with the large wheel, the shaft of the pinion being arranged in a sliding bearing, so as to enable this to be done. There is, therefore, no danger involved in the use of the barring engine, and large engines of 2000 horse-power are thus easily turned by means of very small engines.

The unbalanced action of locomotives and the damaging effects caused by the vibration thus set up upon bridges has led to the suggestion that, for high speeds and long runs, the locomotive should be balanced by using a pair of outside cylinders with their cranks both pointing in the same direction, and two inside cylinders or, in the case of compound engines, one central high-pressure cylinder, with cranks removed just 180° from the outside crank pins. By using exactly the same weight of mov-



A BARRING ENGINE, BUILT BY MESSRS. JOHN & EDWARD WOOD, BOLTON, ENGLAND.

ing parts, a practically perfect balance would thus be secured without any counterweighting for rectilinear moving parts. The one advantage thrown away is the power of starting from any position. Such an engine might stop upon its dead point and could then start only when levered off.

To overcome this defect, the writer has suggested the use of the barring engine. Both the means of balancing and the suggestion of the small engine have been condemned by at least one engineer, but as the latter had evidently not gone to the trouble of calculating the matter out, merely contenting himself with abuse of the suggestion, it may be as well to show figures in proof of the perfect practicableness of the idea.

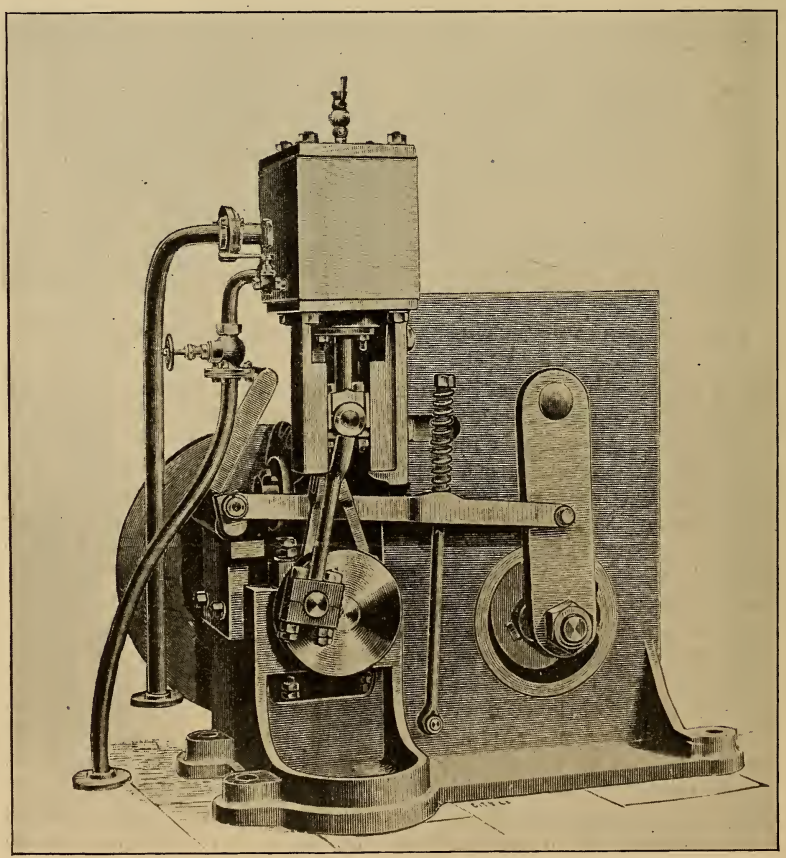
No doubt, one objection is that the locomotive would run unsteadily with cranks at 180° because of its less even crank impulses, but this will soon be shown to be a chimera. Taking the weight of a locomotive and tender at 100 tons and the horse-power generated, at 60 miles per hour, as 1200, we find that for driving wheels of 84 inches diameter the number of revolutions per minute will be approximately 240, and the steam impulses per minute, 480.

The 1500 H. P. engine at the Eagley Mill, at Bolton, in Lancashire, England, may be taken as an example of a single-cylinder engine making 60 turns per minute, with a fly-wheel rim running at 60 miles per hour and certainly not weighing more than 60 tons. The ratio of fly-wheel energy in the two cases is

thus 5:3 in favour of the locomotive. But this ratio becomes 20 to 3 when we consider the greater frequency of the impulses upon the locomotive pistons. One-seventh the momentum of the locomotive will keep going machinery demanding 1500 H. P., with such regularity that the ear cannot detect any change in the hum of the spindles. Nor could the crank arrangement suggested have any appreciable effect in varying the draw-bar pull of the locomotive.

Though the idea of a small barring engine being competent to move the engine of a 400-ton train off its dead points has been ridiculed, and though the Empire State Express train, in the United States, weighs only 143 tons, let us try the question on the basis of 400 tons of train and engine. Let us assume 25 pounds per ton, which implies a starting pull of 10,000 pounds, or very much more than would probably be the case. Now, to move the engine off the dead point will demand a forward motion of 2 feet, or an expenditure of energy to the extent of 20,000 foot-pounds. Allowing such energy to be extended over a period of five seconds, or one-twelfth of a minute, this energy will amount to 240,000 foot-pounds per minute, or, approximately, 7½ horse-power. How can this be secured?

With a small two-cylinder engine, having cylinders 4 inches diameter, a stroke of 6 inches, and a mean effective pressure of 100 pounds, the work, at 200 revolutions per minute, will be 480,000 foot-pounds, or just double the duty required. It is clear then that the train-

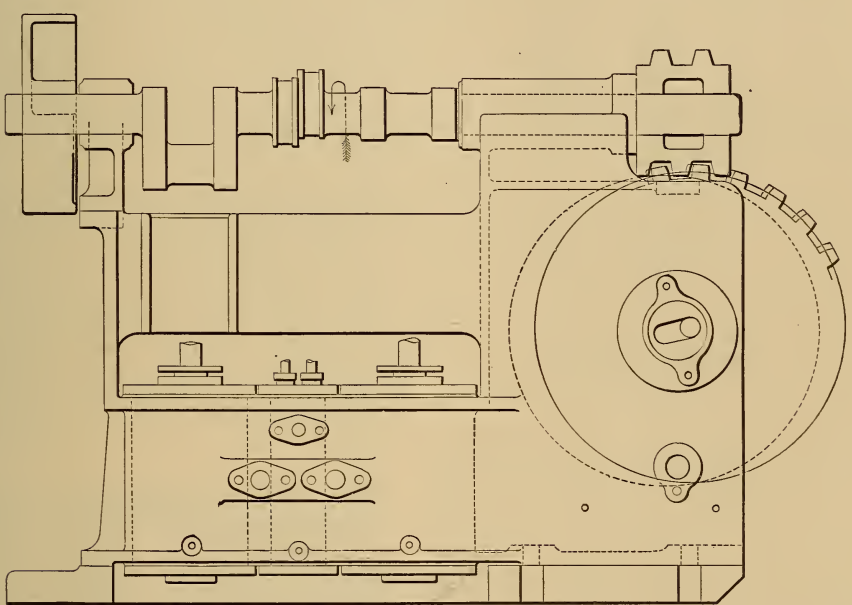


ANOTHER VIEW OF THE ENGINE.

pull may be greater than 10,000 pounds, and the little engine will start it. Thus a 20″ x 24″ locomotive, with a mean pressure of 150 pounds, and a wheel of 84 inches, has a pull of only 13,457 pounds by its one acting cylinder. True, the second cylinder comes in to help as soon as it gets off its dead point, and the total pull may be greater, but the same occurs with the assisted engine. All the cylinders pull as soon as they are moved, ever so slightly, off the dead point, and it is obvious that the condemnation of the idea of a barring engine has no base in fact.

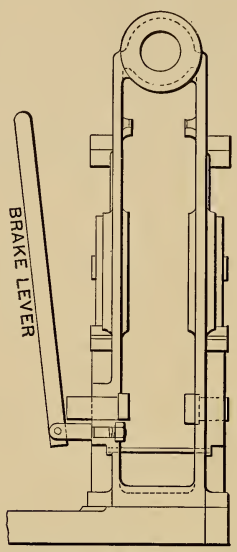
Though occupying little space, a pair of 4″ x 6″ high-speed engines have a considerable power. The ratio of revolutions suggested above, of the starter to the locomotive, is about 1:200. The application of such a starter to the locomotive need not involve complication. The locomotive would run perfectly well with cranks at 180°, and the power of a starting engine of the size named would be ample. Its application to the locomotive would probably be best arranged through a worm gear and friction wheel, pressed upon the driving-wheel rim and applied by a lever, hand or steam actuated.

The barring engine made by Hick, Hargreaves & Co., of Bolton, Lancashire, the leading builders of large factory engines in England, is illustrated in the annexed sketches. The cylinders of this engine are each 9″ diameter with a stroke of 7½″. A worm on the crank shaft actuates a worm wheel which revolves on a shaft, held in slotted bearings. The worm wheel gears direct with a toothed rim within the rope rim of the main driving pulley. The action is as follows :—On starting the barring engine, the brake lever is pushed inwards and nips the lower edge of the worm wheel; the upper edge of the worm wheel is being urged forward by the action of the revolving worm, and the resultant of this and the brake pressure puts the wheel into gear with the barring rim. It will then remain in gear, the pressure of the worm wheel being downward upon the teeth of the barring rim, and the brake may be removed. Then, when the large pulley begins to revolve under the influence of the main cylinders, and commences to run



GENERAL ELEVATION OF BARRING ENGINE, BUILT BY HICK, HARGREAVES & CO., BOLTON, ENGLAND.

quicker than the worm wheel and to drive this latter, the worm becomes the fulcrum upon which, by the now downward pressure on the worm wheel teeth, the spindle of this is caused to slide backward again in its slotted guide, the



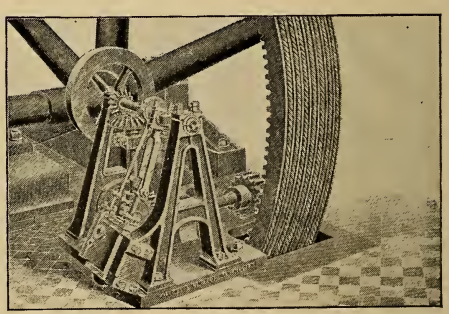
DETAIL OF HICK, HARGREAVES & CO.'S BARRING ENGINE.

slot being slightly inclined to help the action, and the barring engine is thereby thrown out of gear and, if desired, may be made to automatically stop by this same action. There is then no danger of breakage occurring when the large engine begins to move, disengagement taking place automatically.

Apart from the starting of the main engines, the barring engine comes in very usefully, indeed, when putting new driving ropes upon the rim pulley. This is work requiring a considerable amount of barring and not a little power when a tightly-spliced new rope requires lashing to an arm and the rim has to be pulled round until the new rope is fully on. Then, when on, the wheel must still be barred round to transfer the new ropes across the face of the wheel, one groove at a time. All this can be done, it is true, where engines have cranks at 90 degrees ; but there is more or less danger involved in the operation unless there is a barring engine to do the work.

On pages 529 and 530 is shown the engine of another firm of engineers, in which the same end is sought to be attained by slightly different means, the object in all such starting engines being simply to start the main engines from a dead point and pull out of action as soon as the main engine begins to move faster than the starter. These two engravings are from photographs of a barring engine made by Messrs. J. & E. Wood, also of Bolton, and shows a single-cylinder engine in which the engine drives, through the medium of worm gear, a pinion which swings to and fro on a pair of links and is thus pushed out of action when the main engine starts and put into gear by the lever shown.

The smallness and compactness of these barring engines will be clear from the engravings and line drawings, and the ease with which a starting gear could be arranged upon a locomotive will be obvious to any engineer who has not made up his mind that the thing is impossible. For ordinary large engines the ratio of turns of the little barring engine to the main engine is about 1:300.



BARRING GEAR OF A GALLOWAYS ENGINE.

A ratio of 1:200 has been suggested for locomotive work because of the greater difficulty in getting a sufficient reduction of speed. The reduction is not a very serious matter however. A 30-tooth worm wheel and a friction roller of 8 inches, bearing on the tire of the driving wheel would effect the necessary reduction, or the power of the small en-

gine might be transmitted directly to the rail or to one of the wheels of the tender, where tenders, having wheels arranged on the English pattern, are employed. Indeed, the problem is anything but a difficult one. The rotary-motion engine has been here suggested as the means to be employed, but is by no means the only possible device. A single-cylinder with a ratchet-tooth rack piston-rod and a ratchet wheel on one axle, either of engine or tender, would probably be readily devised to meet the case.

ENGINEERING SPECIALISATION AND EDUCATION.

By Professor L. S. Randolph.

THE discussion of the above topic suggested itself in a conversation with the president of one of the large electrical supply houses. In the course of the conversation, he described the following examination to which he had subjected an applicant for employment, who had graduated as an electrical engineer. The young man was asked to calculate the size of wire necessary to carry a given number of incandescent lamps. The calculation was made and the result given in sixteenths of an inch. The applicant failed to get the position, principally because he had not seen that it was necessary to know what size lamps were to be used, and, second, because the results were submitted in sixteenths of an inch instead of by wire gauge, or, at least, decimals of an inch. Without attempting to discuss either the examination or its results, we see what is more important,—the tendency on the part of employers to require that technical graduates shall be capable of making themselves at once useful, and to measure their usefulness by their ability to solve everyday, practical problems.

It has been the custom in teaching engineering, to select such problems for illustration and practice, as will bring out the practical side of the question as much as possible, and show the application of the theory being investigated. In selecting these problems, the question at once arises,—What problems most fully illustrate the subject, and, having two or more given problems, which one will be most likely to be of use in the graduate's future career?

While it is absolutely essential that the education of an engineer should be broad, and not confined to any one specialty to the exclusion of all others, it is yet important that special stress should be placed on those lines of work in which there is the greatest likelihood of obtaining remunerative employment. The question, "What is the young man best fitted for?" can only be answered by a careful study of the ability, temperament, idiosyncrasies and physical health of the individual, and not always then can one be sure that he is right, or that the natural development of the man will not upset all of his calculations. The question, "In what special lines of work is there the greatest demand for technical graduates?" is of the utmost importance to the technical educator as well as the student.

In the following solution of this problem, having especial reference to the course in mechanical engineering in the United States, much difficulty was encountered in obtaining definite information, as it was seen that to get accurate information as to the duties and occupation of all of the engineers of the country would be out of the question. It was considered, however, that the membership of the principal engineering societies would fairly rep-

resent the engineering profession, and from this source, the distribution of the engineers through the different occupations was obtained. Even here much difficulty occurred on account of the vagueness of many of the titles. The large percentage marked "indefinite" will show how great this difficulty was. In these cases, the positions held were such as would not have affected the result at all, and from the marked difference between the various specialties, it is very evident that more detailed information would not have altered the result.

In classifying superintendents and managers, all those were included whose duties seemed to be more completely executive than engineering. Under this head were included all superintendents of motive power and railway master mechanics. With the latter class, the duties are almost entirely executive, while with the former, in the majority of cases, their duties are executive principally, although in some few cases, the organization is such that the superintendent of motive power is practically a consulting mechanical engineer.

In the American Society of Mechanical Engineers, the following distribution was found:—

	Per Cent.
Mechanical engineers in employ of firms or corporations	18.1
Mechanical engineers in railroad service	.6
Mechanical engineers in consulting practice	6.7
Draughtsmen	2.3
Master mechanics of industrial establishments.	.89
City engineers, hydraulic engineers, supt. waterworks	.77
Electricians	.74
Marine engineers, naval architects and engineers in navy	1.42
Engineers in army or on government work	.83
Civil engineers	1.35
Metallurgical engineers and chemists	.37
Agents of manufacturing firms	2.17
Editors of technical papers	.74
Presidents and vice-presidents of firms or corporations	9.87
Superintendents, managers and other executive officers	20.90
Superintendents and managers of railroads	2.00
Proprietors of industrial establishments	5.31
Secretaries and treasurers	1.72
Professors, assistant Professors and instructors.	5.39
Indefinite	17.51

Taking one of the most prominent schools of technology which gives the degree "M. E." only, we find the distribution of its graduates as follows:—

	Per Cent.
Mechanical engineers in employ of firms or corporations	17.74
Consulting mechanical engineers	8.06
Mechanical engineers in railroad service	2.30
Electricians and electrical engineers	6.22
Draughtsmen	9.44
Mining engineers	.46
City and hydraulic engineers	.69
Architects	.46
Agents and supply men	1.83
Presidents and vice-presidents of corporations.	2.76
Proprietors	2.07
Supts., mgrs. and other executive officers of firms and corporations	14.75
Supts., mgrs. and other executive officers of railroads	1.84
Secretaries and treasurers	1.67
Professors, assistant professors and instructors.	5.76
Editors of technical papers	1.15
Lawyers or patent solicitors	1.15
Chemists, contractors and civil engineers	.92
Indefinite	20.74

We find here a fairly close approximation with the mechanical engineering society in the percentages of mechanical engineers employed permanently, and consulting mechanical engineers and city or hydraulic engineers, but the percentage of mechanical engineers in railroad service and electrical engineers show quite a difference. This can be readily accounted for by remembering that both of the specialties have flourishing organizations of their own, which, in all probability, attract these men more than this society. In both cases the large percentage of executive officers is rather remarkable. In the society executive officers constitute 39.80 per cent. of the whole, and among the graduates of the school, 22.94 per cent.

In the American Society of Civil Engineers, we have:—

	Per Cent.
Civil engineers employed by firms and corporations	4.50
Civil engineers (consulting)	21.60
City and hydraulic engineers	12.27
Engineers in employ of railroads, including chiefs, road masters, etc	13.10
Engineers in service of general government	6.52
Mining engineers	.67
Architects	.25
Mechanical engineers	.76
Electrical engineers	.08
Proprietors	.84
Presidents and vice-presidents	4.73
Secretaries and treasurers	.58
Superintendents, managers and other executive officers of firms and corporations	3.39
Superintendents, managers and other executive officers of railroads	2.79
Editors	.42
Agents, contractors and chemists	.80
Indefinite	23.50

We obtain some very interesting results by comparing these figures with those afforded by the Society of Mechanical engineers. With the Society of Civil Engineers, the percentage in the employ of corporations and firms is about the same as the consulting me-

chanical engineers, and the percentage of the Mechanical Engineers' Society in the employ of corporations and firms is about the same as the percentage of consulting civil engineers. When, however, we include engineers on railroads and city engineers, whose duties are more or less executive, we find that the percentage of Civil Engineers' Society members permanently employed is much greater than the percentage of members of the Mechanical Engineers' Society in permanent employment. This would seem to negative the objection so often made to the profession of civil engineering of not being permanent, even if we concede that one-half of those employed on city or railroad work were on construction, which would throw them out of employment as soon as the work was completed.

The number of railroad mechanical engineers in the American Society of Mechanical Engineers is very small compared with the number of civil engineers on railroads, which would indicate that there was little room in this line of work, but for the fact that it was only within comparatively recent years that technical graduates and men of a class who would join such a society, have been going into the mechanical department of railways, and the existence of an association devoted to railway mechanics. The larger percentage shown in the mechanical school would indicate that the younger men are going into this line, and gives an idea of the room which undoubtedly exists here.

A question which has given the writer much difficulty is—whether it would pay to spend much time, in a mechanical engineering course, on water supply and sewerage. The small number of mechanical men in this work would indicate that it would not, and, yet, this would seem, for many reasons, to be a field which could be well filled by them.

One of the most interesting comparisons is that between the percentage of executive officers and engineers:—

	Per cent.
Total engineers in A. S. M. E.	30.19
In Am. Soc. C. E.	58.06
Total ex. officers in A. S. M. E.	39.80
In Am. Soc. C. E.	12 33

That is, nearly five times the number of Civil Engineers are employed as such rather than in executive positions, whereas, nearly one-third more Mechanical Engineers are employed in executive positions than in engineering proper.

In order to see what lines the recent graduates in civil engineering are taking, the following distribution was taken from the list of graduates of one of the leading American colleges, which makes a specialty of this line of work:—

	Per Cent.
Civil engineers employed by firms, corporations, etc	13.59
Consulting civil engineers	13 20
In service of general government	2 97
In railroad service	9 10
City engineers	7.06
Mining engineers	2.04
Chemists	1.30
Mechanical and electrical engineers	1.30
Professors, assistant professors and instructors.	4.64
Proprietors of manufacturing establishments	4.64
Presidents and vice-presidents	2.74
Superintendents and managers	12.27
Secretaries and treasurers	2.04
Law	1.30
Agents, contractors, architects and supply men	2.72
Editors	.37
Other professions	5.94
Indefinite	10.59

These figures were taken for the period subsequent to 1870, as it was considered that they would represent more nearly present tendency. We find here somewhat different results than were obtained in the case of the Society of Civil Engineers. A larger percentage is employed by firms and corporations and a somewhat smaller percentage by railroads and cities. We find, what is rather surprising, a larger percentage of civil engineers engaged in executive work among the graduates of the school than among the members of the society, and nearly as many as among the graduates of the school of mechanical engineering.

The objection may be raised to this method of treating the subject that it does not accurately represent the demand for engineers, and it must be admitted that it is not rigidly exact, but it is, without doubt, true that it is approximately correct.

No attempt was made to study the subject of mining engineering from the same standpoint, as it was considered

that this field was practically closed to the mechanical specialist, on account of the intimate knowledge required of geology and metallurgical processes taking far more time than could be spared in the ordinary four years' course. The subject of electrical engineering was not considered separately any more than hydraulic or compressed air engineering, because it was considered a department of mechanical engineering. The mechanical engineer does not deserve the title unless he be also an electrical engineer.

The above would indicate that the most important specialties which must be cared for in the mechanical engineering course are electrical and railroad engineering.

In many of our colleges, the value of these two are so fully realized that special professorships are maintained for them, and in some colleges a special degree of "Electrical Engineer" is given, while in other places, the electrical engineering is made subordinate to, and considered a requisite of, mechanical engineering.

The small percentage of city or hydraulic engineers would indicate that there was little use for work in this line.

The comparatively large percentage of engineers engaged in teaching shows that this is of some importance; it would seem that a well organized course of study and a thorough system of instruction would make an object lesson which would be all that was needed in this line. The most important deduction which we can draw from these tables is the necessity for more attention to the executive part of engineering. That this is of extreme importance, cannot for one moment be denied, when we consider that in the Am. Soc. of M. E. there are one-third more executive officers than engineers.

The necessity of having someone at the head of affairs who has the necessary technical knowledge to direct and control his subordinates, has long been recognized and is fully appreciated, but the men who take these positions must learn this side of their business only by hard knocks, and as the opportunity offers, unless the subject is taken up and taught systematically to our technical graduates.

EDWARD H. CARBUTT.

Past President of the British Institution of Mechanical Engineers.

UP to some twenty years ago Mr. Carbutt's name was well known in engineering circles in England, as a partner in the firm of Messrs. Thwaites & Carbutt, of the Vulcan Ironworks, Bradford, now carried on under the style of Thwaites Bros., Limited. Mr. Carbutt retired from that firm after a partnership connection of about fifteen years, and the high position which that firm occupies in the engineering world, has followed as the result of the technical ability and clear-headedness which the personality of the proprietors brought to bear upon the business operations of the concern.

In 1887 and again in 1888 Mr. Carbutt was selected to act as president of the British Institution of Mechanical Engineers. This, in itself, is sufficient to show the high honour in which Mr. Carbutt is held among those in the profession to which his life has been chiefly devoted. Former presidents of the Institution have included the names of Lord Armstrong, Sir William Siemens, Sir Frederick J. Bramwell, Sir Joseph Whitworth and Sir Lowthian Bell among other well-known names, and Mr. Carbutt has proved himself no unworthy successor.

Since retiring from business, Mr.

Carbutt has devoted his mechanical knowledge and his energy to the furtherance of engineering interests in a more public capacity. England is indebted to him for having obtained a committee of inquiry into the question of Indian railways, and the result of the report issued by that committee was the recommendation of a considerable extension of the State system. Mr. Carbutt also, as a member of Parliament, took a leading part in advocating the cause of Indian civil engineers engaged in the Public-Works Departments. He is, moreover, well known as having moved for a committee to inquire into the design and supply of guns, and into the organization of the Government works at Woolwich, Enfield, Waltham and Birmingham.

Mr. Carbutt is a native of Yorkshire, the inhabitants of which county are regarded as pre-eminent for their business capacity, their industry, and their clear-headedness. During his connection with the firm of Thwaites & Carbutt he was actively engaged in making iron and steel works machinery, gun forging machinery, steam hammers for gun forging for the Russian government, including one of 50 tons, and other tools, among them a 25-ton hammer for the Armstrong Works, Newcastle. Mine ventilating machinery was another class of apparatus to which special attention was given by the firm, and in this department they achieved a high reputation. Mr. Carbutt was also one of the leading spirits in the project for erecting a great tower in London, on the plan of the Eiffel Tower. He was a member of the Tower Company, Limited, and he was appointed chairman of the Committee of Jurors selected to adjudicate upon the merits of the designs sent in, in competition, under the offer of a 500-guinea prize.

Current Topics.

THE fact that the use of oil as an anti-incrustator in steam boilers should be occasionally attended by bagged furnace crowns, if nothing worse, continues to be a source of wonderment to a good many people who ought to know something of the possibilities of the oil treatment. It has been pretty well demonstrated that a very small globule of oil, on becoming attached to the inner side of a boiler sheet, will sometimes collect a mass of dirt particles contained in the water, and that the whole mixture will ultimately bake on and form an excellent non-conductor. This being the case, the overheating and

bulging of the sheet at that particular place are quite in the regular order of things. The only specially noteworthy thing about the matter is that a very thin film of oil and a very small admixture of dirt are sufficient to do a great deal of harm, and that the scale formed by them may be so inconspicuous as to readily escape detection; hence, the seeming mystery which sometimes attends the coming down of a crown sheet.

LOOKED at from whatever point of view, the recent performance of the United States cruiser "Columbia" in crossing the Atlantic, from the Needles, near Southampton, to Sandy Hook lightship, off the American shore, in a little less than seven days, is unparalleled in naval history. We have become so accustomed to hearing of phenomenal bursts of speed of war ships of all naval powers on measured mile runs, only to be told in almost the same breath that these speeds are never really counted upon as possible of attainment in subsequent regular work, that a seven-day trip across the Atlantic by any man-of-war was, until now, considered quite beyond the realms of likelihood. Trial trip records, it must be remembered, are made with the ship fresh from the dry-dock, with a clean bottom, a picked crew, picked coal and the best of weather, and with every possible human precaution taken to get, in the short period of four hours, the utmost that is in the vessel in point of speed,—something far above the average. Once through the trial, the ship, which has thus attained the rank of a 22-knot vessel, mayhap, often settles down to a plane of comparative mediocrity, and is not apt to be again called upon to practically demonstrate that she was at one time capable of doing that with which she has been credited by the official records. In the machinery of the modern fighting ship, much has been sacrificed to a saving in weight and space, and to the disposition, as nearly as possible, of boilers and engines below the water line. The designer has not had that freedom which is to be found in the planning of any of the fast Atlantic liners' engines, in which reliability of working at maximum duty, day after day, for 24 hours a day, is the prime consideration, unrestricted by cramped space, the possible effects of an enemy's fire and other conditions little less obstructive to the securing of the best speed results for long continuous periods of time. That a modern cruiser should be able fully to hold pace with one of the crack

THE UNITED STATES CRUISER "COLUMBIA." TRIPLE SCREWS. HORSE-POWER 20,000.

ocean greyhounds, popularly supposed to be invincible in speed, is, indeed, one of the desiderata aimed at in theory, at least by all naval authorities, but to accomplish this is quite another thing. It is not too much, therefore, to repeat that the performance of the "Columbia" in racing successfully, as she did, against so splendid a steamship as the "Augusta

THE THREE PROPELLERS OF THE "COLUMBIA."

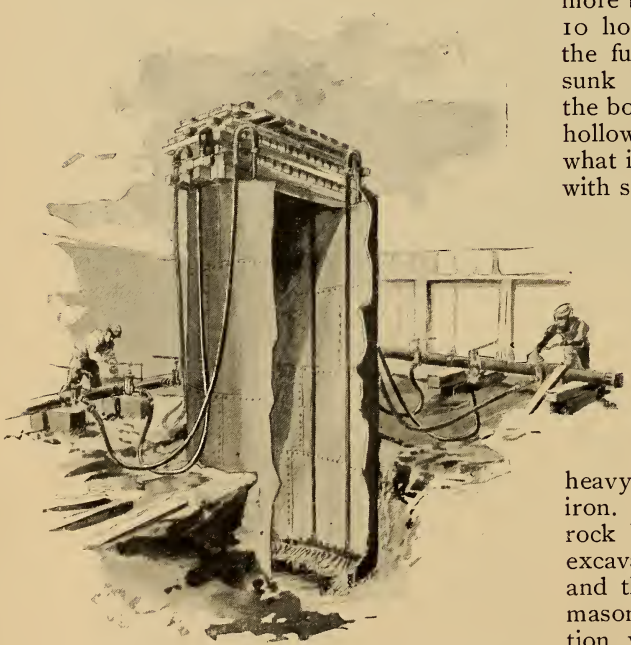
Victoria," of the Hamburg-American line, stands unparalleled among ships of war, and ought to be a source of genuine pride to the United States Navy Department and the Bureau of Steam Engineering, as well as to her builders, Messrs. Cramp & Sons of Philadelphia.

THE actual time of the "Columbia" between the Needles and Sandy Hook was 6 days, 23 hours and 49 minutes, covering the distance of 3579 miles at an average speed of 18.54 knots, or about 21.3 miles an hour. The best four-hours' run during the trip was 92½ miles. The distance covered by the "Augusta Victoria" from Cherbourg was 3502 miles, and her time of passage was 6 days, 20 hours and 20 minutes, steaming, therefore, at the same rate of speed as the "Columbia." It may not be uninteresting to add here that the official description of the "Columbia" calls her a protected cruiser, 412 feet long, 58 feet beam and 22 feet 6½ inches deep, with a displacement of 7350 tons. Her keel was laid in 1890, and her launch took place on July 27, 1892. Her contract price was $2,725,000 (£545,000). This was for a speed of 21 knots, and $350,000 (£70,000) were added to this for premiums for increased speed over the contract requirements. Her armament, as she is intended for a commerce destroyer and not for a fighting ship, is comparatively light, and consists of one 8-inch breech-loading rifle, two 6 and eight 4-inch rapid-fire guns, twelve 6-pounder and two 1-pounder rapid-fire guns and four Gatlings.

WITH the promise that there seems to be, especially in continental Europe, of quite an extensive use of street cars propelled by gas engines, it is worth noting that the question whether the gas-motor car would be able to meet successfully the difficulties incident to cold weather and sudden snowfalls, would seem to have been satisfactorily settled by the experience, in Germany, of the past winter, which was exceptionally long and severe. From a statement published in the *Journal für Gas Beleuchtung*, it appears that at Dessau there fell on the 4th and 5th of January nearly twelve inches of snow, followed by several days of intense cold, during which the temperature fell to 8 degrees Fahrenheit, or 24 degrees below freezing. During this period the service on the local gas motor street car line was maintained regularly and without interruption, except on a short section where, through neglect to strew salt before the storm, the grooves of the rails were filled with hard ice, so that the cars would not keep the track. This obstacle was, however, soon removed, after which the cars ran on regular schedule time over the whole line, driving through the heaviest drifts, and, when necessary, pushing a cleaner car in front. No difficulty occurred through the freezing of the water-jackets of the engines or the reservoirs, the warm water coming from

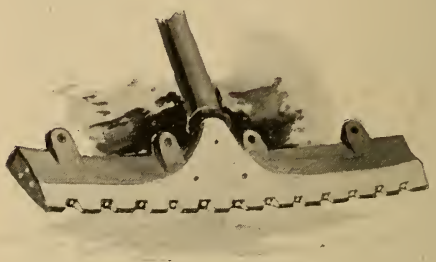
the cylinders keeping that in the reservoir and pipes above the freezing point. At Dresden the gas-motor cars ran regularly throughout the winter, while on several days the electric cars there were stalled, and at Lübeck, Erfurt and Halle the electric tramways had stoppages of several hours' duration, and even the horse-cars fared little better.

WHILE the use of water-jets for pile driving and earth excavation is not new, having been practised successfully for thirty, if not more, years, for example, during the great American Civil War, when tree trunks were sunk in some of the rivers by means of water-jets so as to obstruct the passage of gunboats, yet a substantially new application of the method was recently made in New York, in connection with the



SINKING CAISSONS BY MEANS OF WATER JETS.

sinking of caissons for the foundations of a big building. The annexed sketch pretty fairly illustrates the manner in which the plan was carried out, the details of the method having been perfected by Mr. Wm. D'H. Washington, the general manager of the Hydraulic Construction Company, of New York, who had the contract for the work. The caissons were open



A PART OF THE CAISSON SHOE.

steel cylinders, about 27 feet long and from 6 to 13 feet in diameter, according to the load which the foundation had to support, and were sunk through a stiff, quick-sandy soil to rock, 40 feet or more below the pavement, in from 2 to 10 hours each, the contract requiring the full number of 44 caissons to be sunk in 50 working days. Around the bottom of each cylinder were bolted hollow cast-iron shoes, shown somewhat in detail in the second little sketch, with serrated and perforated edges from which water under high pressure was forced. The effect of these numerous water-jets, of course, was to loosen the earth around the lower edge of each cassion and thus burrow a path for the latter to follow, which it did at the surprising rate of speed of about an inch a minute, aided by a heavy superimposed weight of pig-iron. When the caissons reached rock bottom, the interior of each was excavated, a concrete bottom put in, and the remainder filled with brick masonry. The usual deep foundation work accompaniments of compressed air locks and the necessary attending machinery, not to mention the inconvenience to the men of working in compressed air, were entirely avoided. What would not less command itself, however, was the already-mentioned great speed with which the

work went forward, and which, under even the most favourable conditions, is noteworthy.

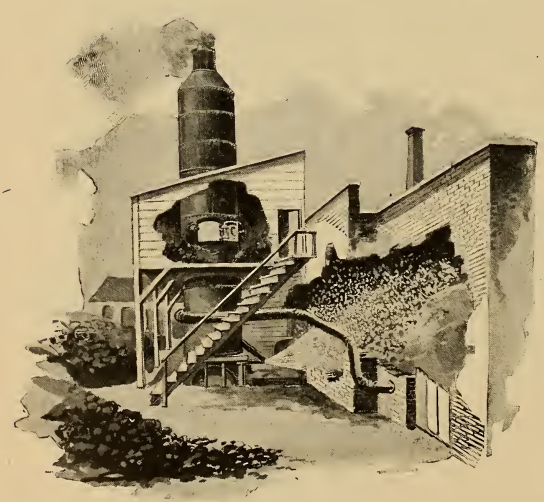
ANENT the use of compressed air in machine and boiler shops and foundries, for working machine tools and lifting apparatus, and for doing miscellaneous work, as detailed in an article in the August number of this magazine, by Mr. Charles O. Heggem, it may be of interest to add that at the works of the American engine builders, Messrs. Russell & Co., at Massillon, Ohio, of which Mr. Heggem is the superintendent, compressed air has been used for power transmission in the various ways outlined for six or seven years past. To-day, these works have in operation twenty-six 5-ton cranes, one cupola stock elevator, and a large number of small hoists, ranging from 400 up to 1000 pounds capacity, besides a collection of shears and punches in their boiler shop, all operated in this way, and with most excellent results. With one form of compressed air shear, applied to the cutting-off of stay bolts in locomotive boilers, somewhat after the manner illustrated in Mr. Heggem's article, two boys can cut off 700 or 800 bolts per day of ten hours, which is far in excess of what could be accomplished by hammer and chisel in the old way. Correspondingly greater economy and convenience have been found to result in the various other applications of compressed air in these shops.

THE air is supplied by three compressors. A belt-driven compressor, 13 x 10 inches in size, runs constantly, and supplies most of the air that is used. The working pressure is from 60 to 70 pounds. A 7½-inch by 7-inch steam-driven duplex compressor is controlled by a pressure valve, so that when the pressure of air falls below 60 pounds, this compressor is started to supply the deficiency. The air supply is thus maintained automatically. A smaller, steam-driven compressor is kept merely as a reserve in case of accident to either of the other machines. The air is stored in three reservoirs of 250 cubic feet capacity each, placed in those parts of the works where the greatest volume of air is required. Owing to the intermittent use of the air these compressors are able to furnish a sufficient amount and at a cost of something like $3, or about 12 shillings per day of ten hours.

AMERICA'S metropolis, the city of New York, at last has in operation an electric open-conduit street railroad which will probably prove satisfactory to the public as well as to the company operating it. It is strange, indeed, that a problem relatively so simple as the building of a successful road of this kind should have been held up for so long a time as one of the bugbears of practical engineering. Electric conduit roads, it is true, there have been many, some on paper and some in actual service, but of these latter the one at Budapest is the only one which has heretofore been distinctly successful, not so much because of any specially remarkable feature of construction, as because of the favourable condition of that city's streets, which have always been held up as models of good paving and cleanness. Serious filth accumulations in the Budapest conduits, and consequent traffic interruptions, have therefore been almost unknown there. What has proved itself to be good practice at Budapest, however, was not necessarily good practice in every other city, particularly not where clean streets were the exception rather than the rule and where the conduit was likely to be called upon, at almost any time, to carry off large quantities of storm water. Too great a saving in the first cost of construction and, as a rule, therefore, too small a conduit have sealed the fate of nearly every open-conduit road thus far built, but instead of recognizing this as the true difficulty, inventors have, in the main, sought to supplant the open conduit by various other forms, nearly all of them much too complex and delicate to warrant serious thought of their

adoption. The result has been hundreds of patents, more or less interesting, but practically worthless. The open-conduit idea is quite good enough, but it should be worked out with an ordinary amount of common sense, and with due regard to the plain fact that extreme economy in cost of conduit is no economy at all. Make the conduit big enough, so that dirt falling into it will not quickly fill it up, and ordinary rain storms will not be able to flood it; then you will have satisfied the underlying principle of success. Of this the New York line referred to will, in all probability, give further proof, and in so-doing, will mark a distinct advance in the matter of street car propulsion in big cities.

Of those who know what mineral wool is, or silicate cotton, as it is sometimes called, probably only a small number are familiar with the simple process by which it is made. The wool itself, serving a variety of useful purposes, as a non-conducting covering



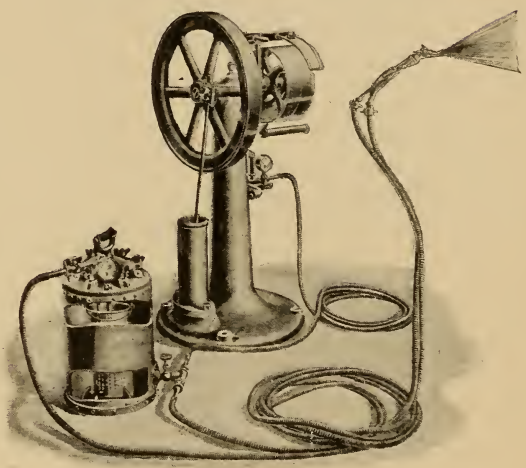
"BLOWING" MINERAL WOOL.

against heat and cold alike, for steam pipes and cold-storage room walls, as a sound "deadener" in floors of buildings and as a means of fire-proofing, among many others, is, as its name implies, a soft and wooly substance, consisting of a mass of very fine mineral fibers, interlacing one another in every direction, and thus forming an endless number of minute air cells. The wool appears on the market in a variety of colors, principally white, but often yellow or gray, and occasionally quite dark, and is made by converting scoriæ and certain rocks, while in a molten state, into a fibrous condition by a steam blast directed against the liquid material. Probably no better idea can be given of the nature of the process than by the annexed sketch which almost speaks for itself. Blast furnace slag forms the raw material for one variety of the wool, and sandstone for another, yielding, respectively, slag wool and rock wool, the latter being preferable for pipe covering because of the absence from it of sulphur, which, with moisture present, becomes an active corroding agent. The furnace slag or the rock, as the case may be, is melted in a large cupola, and as it trickles out at the tap hole in a somewhat sluggish stream, it meets a high-pressure steam jet which atomizes the woolen mineral, if this term may be used, blowing it in fleecy clouds into the storage room provided for it. Soft and downy, the stuff settles wherever a resting place affords itself, the heavier and coarser wool coming down first, while the lighter portions are blown further along by the force of the steam, and settle in the more distant parts of the room. The material thus naturally grades itself into varieties of different quality. A thousand pounds of wool per hour are turned out by one of the cupolas, and after the storage room has been blown full, the flocculent mass is packed into bags, ready for the market. The whole process affords an admirable and interesting illustration of the utilization of an utterly waste product.

Painting by machinery, practised on a large scale for the first time in connection with the mammoth exposition buildings at Chicago, in the United States, in 1893, has become an every-day accomplishment, and painting ma-

chines are now regularly purchasable articles, being made by at least one English firm, Messrs. A. C. Wells & Co., of London and Manchester. For several years previous to the mentioned use, at Chicago, of ordinary garden hose and spraying nozzle outfits, by means of which the immense areas of wall space in the Fair buildings were coated with paint and kalsomine, a substantially similar plan had been, and still is, followed at some of the American railroad shops for painting shop walls, freight cars and the like, but the appliances there used, though very serviceable and time-saving, were "home-made," and could scarcely be considered as articles of commerce. Now, however, the intending user of a painting machine need no longer resort to a make-shift apparatus, but can buy it in the open market, in various sizes and forms, just as he would buy any other standard piece of machinery.

In the particular machine in question, the paint or kalsomine is atomised and sprayed on to the work by a stream of compressed air, just as in the earlier contrivances of this kind. From a small air compressor the air is led, through flexible hose, to a paint tank, which is provided with an air-tight cover and clamping screws. The paint is contained in a pot which can be readily removed and replaced by another when a different colour is required. This arrangement of interchangeable tins is also important, as facilitating easy cleaning. The container is furnished with a semi-rotary stirrer, the spindle passing through a stuffing-box in the cover, and ending in a handle by which the whole thing complete may be carried about. The compressor is necessarily fixed or stationary, but the paint tank, connected to it by the single air hose, can be moved close to the work, while the length of hose from the tank to the nozzle gives the freedom of movement necessary. Air pressure is admitted to the tank by a bottom valve, and forces the paint up an internal pipe and along a hose from the tank top to the spraying nozzle, to which air pressure is also led by a second hose, as shown in the appended sketch, which has been reproduced from the London *Engineer*. The nozzle is practically an injector of special form. The flow of paint at the nozzle is controlled by a small plug valve and spring lever on



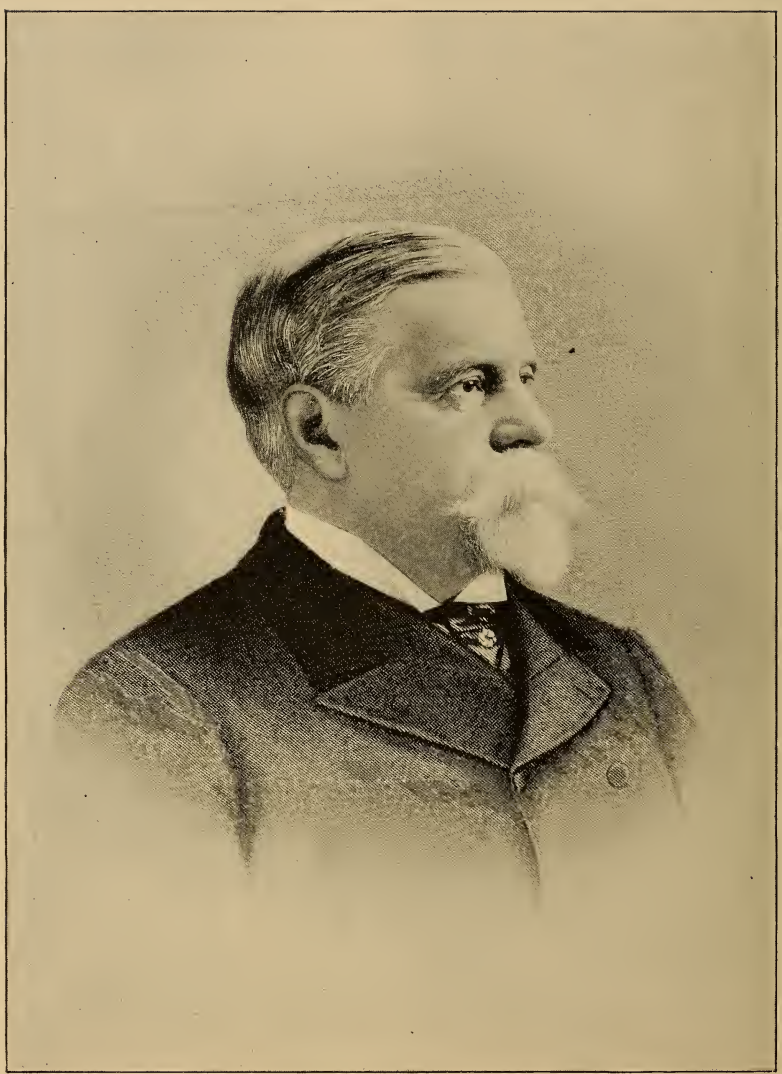
PAINTING BY MACHINERY.

which the operator keeps his thumb while working, and which, on release, closes automatically. Much difficulty has always been experienced from the tendency of small-way valves of this class to become choked by particles or pieces of skin, or silted-up paint sediment. In the machine shown, this is overcome by an ingenious arrangement, whereby the nozzle, with a further movement of the spring lever, is directly connected with the air pressure, and the obstruction blown out. When it is required to change from one colour of paint to another, or to use a different material, such as varnish, the can, previously in use, is removed, and air, or if necessary, paraffin oil, is blown through the length of hose which supplies the paint, until it is completely clean. This is readily effected in a very short space of time.

As an instance of the rapidity with which such a machine can work, it has

been stated that a 30-ft. by 8-ft. boiler can be covered in less than an hour, and at one large bridge yard, where the apparatus is in constant and successful use, a plate girder—70 ft. by 6 ft. by 2 ft., with gussets, verticals, etc.—was coated with boiled oil by one nozzle in two hours,—more than equal to a full day's work for a man with a brush. A further advantage claimed is that cheap common paint, of which two coats are necessary if put on with a brush, can be laid on so perfectly by the spray that a single coat is ample. Should a second coat be advisable, it can be put on without waiting for the paint to dry, and the saving of time from this fact alone is very great. For better class joinery and cabinet work, the machine has the merit of producing a perfectly smooth surface, which, being free from brush marks, does not require rubbing down and repeated coats to bring it to a face. For decorative or relief work the spray is admirably adapted, since it penetrates to the most minute recesses, which could only be reached clumsily and slowly by a brush, and covers the whole surface evenly, rapidly and smoothly without either blunting the outlines or unduly filling in the depressions.

MUCH has been made, of late, of the electrical operation of farm machinery, and there are now in existence a number of installations in which electric motors have entirely displaced steam engines and boilers for hauling plows, and driving mowing, threshing and other agricultural apparatus whose functions, in turn, not many years ago, were modestly performed by hand labour. Probably the latest of these electric agricultural outfits, and the first that has been introduced into France, is mentioned in the *Moniteur Industriel*, being on the estate of M. F. Prat in the Tarn district. A suitable water fall was available on the property, affording about 30 horse-power through a turbine which was coupled direct to an electric generator, capable of furnishing a current of 40 ampères at 375 volts. Through the centre of the estate, measuring somewhat over a mile across, run overhead electric wires, carried on poles in the usual way, and from these the current is taken off wherever required. The power, at present, seems to be used mainly for plowing, through the medium of an electric windlass, which is driven by an 18 horse-power motor. The windlass carries two rope drums and rests on a track which can be moved along rails, laid directly on the ground, so that the whole hauling machinery can be moved along as furrow after furrow is completed. Two insulated cables, about 650 feet long, connect the windlass motor with the overhead line, and can be wound upon, or unwound from, a special drum, forming part of the windlass outfit. Connections between the insulated cables and the line wire is effected by suitable clamps, which can be easily unfastened and moved along as occasion may require. The hauling cables are about 800 feet long, so that the plow can readily be made to work over a length of about 1400 feet. One of the incidental advantages afforded by the installation, not counting the driving of other machinery on the farm from it, is the possibility of lighting up the whole property with current from the main line, and thus enabling the carrying on of field work at night, should it be found desirable, as it sometimes is, to do so.



J. M. Allen

PRESIDENT OF THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

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CASSIER'S MAGAZINE.

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WELL AT SPRINGFIELD, S. D., U. S. A. DEPTH, 593 FEET; DIAMETER, 8 INCHES; PRESSURE OF WATER, 130 POUNDS PER SQUARE INCH.

POWER FROM ARTESIAN WELLS.

By A. L. Baumgartner.

THE first discovery of deep artesian waters in South Dakota, in the United States, was made in 1881, at Aberdeen, in the famous James River Valley, that traverses the entire State from north to south. In the summer of that year the Chicago, Milwaukee and St. Paul Railroad Company commenced to sink a 6-inch well to secure water for their engines. The company was fully determined to sink the well as deep as possible in their efforts to se-

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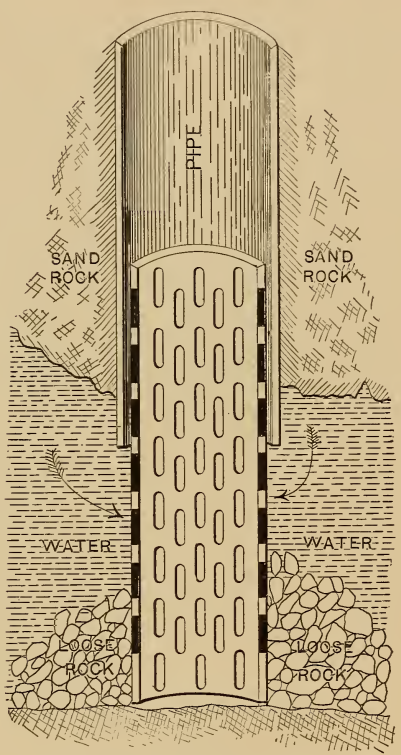
WELL AT YANKTON, S. D., U. S. A. DEPTH, 500 FEET; DIAMETER, 8 INCHES; PRESSURE OF WATER, 35 POUNDS, WORKING THROUGH A 3-INCH NOZZLE.

cure an abundant supply of water, the want of which caused them a great inconvenience. In the spring of the following year a flow of 1000 gallons per minute was struck at a depth of 920 feet. The progress of this well was watched with great interest, and its success was followed by others, until, at this time, the number of wells, large and small, reaches into the hundreds throughout the great basin which extends over a territory 400 miles north and south, and 150 miles east and west. All the wells thus far driven are located east of the Missouri river.

Generally speaking, the artesian waters are used for all the purposes of city supply, and also for irrigating work. In several noteworthy instances, however, the water, coming as it does, from the wells under high pressure, is used as a source of power, and a number of manufacturing establishments are now being driven by it through the intervention, principally, of Pelton water wheels. It is only within the past few years, however, that artesian well power has been thus brought into service, though with the better appreciation of its importance a much wider application of it seems definitely assured.

Among the more noteworthy of the wells is the famous one at Woonsocket, S. D., in the United States,—the most powerful in the world. It is 775 feet deep, 7 inches in diameter all the way, and has a flow of 5000 gallons per minute, with a pressure of 165 pounds to the square inch when closed, 62 pounds with a 4-inch opening, and 75 pounds with a 3-inch opening. The temperature of the water is 61.0° F. The power from this well is used to operate the Woonsocket Roller Mill. The mill has a 3-foot Pelton wheel, which is kept at a speed of 275 revolutions per minute with a 1¾-inch stream. The mill turns out 90 barrels of flour and 40 tons of feed every 24 hours, at a saving of $20 or about £4 per day as compared with steam power of equal service.

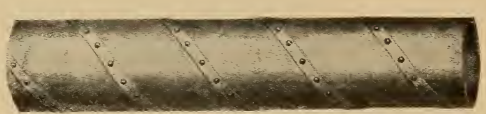
The well at Springfield, S. D., is 593 feet deep and 8 inches in diameter all the way. The pressure there is 130 pounds. The power from this well is used to operate the Springfield Roller Mill, with a capacity of 80 barrels of flour per day. The wheel used is a



AT THE BOTTOM OF ONE OF THE WELLS.

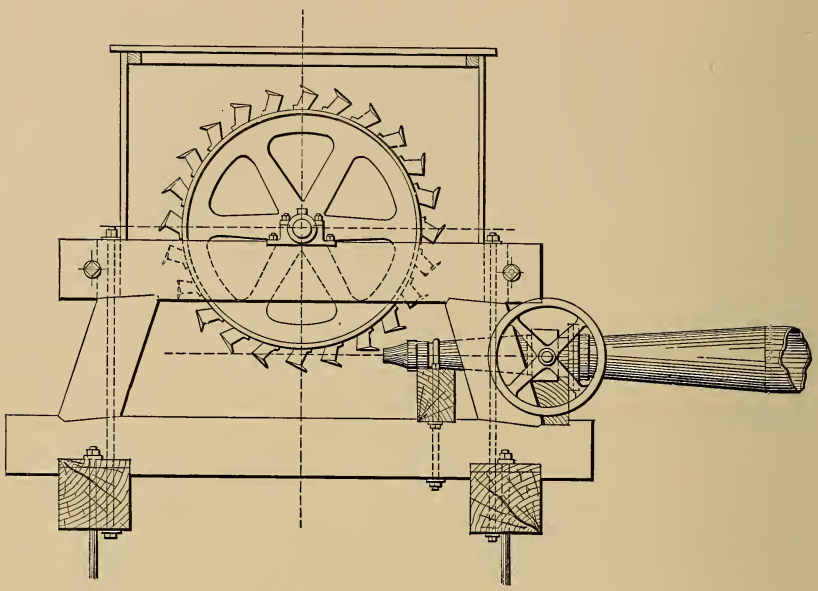
16-foot turbine making 800 revolutions per minute. The proprietors of this mill figure on a saving of $15, or about £3, in feed per day.

At Yankton there is another well, 500 feet deep, with a pipe eight inches in

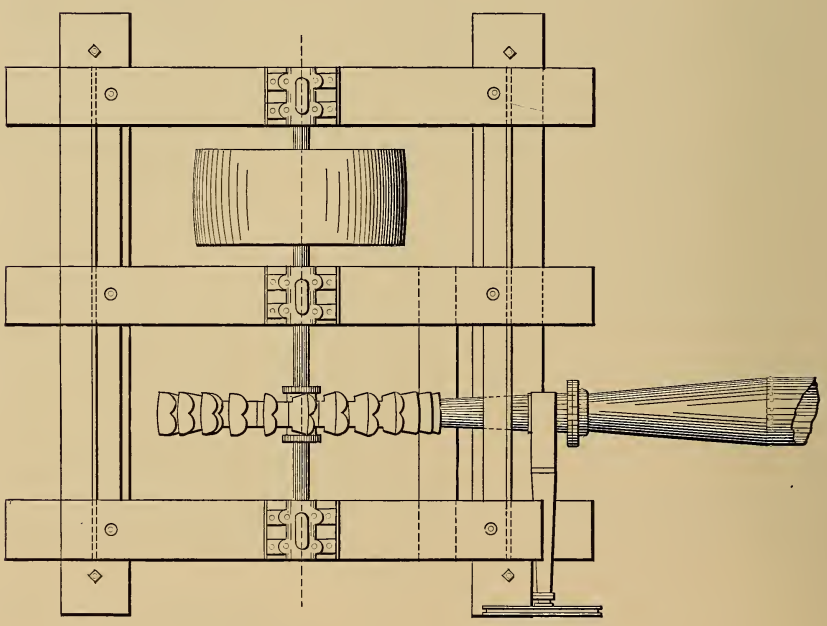


A PIECE OF SPIRAL RIVETED WELL PIPE.

diameter to the bottom, and affording a pressure of 125 pounds per square inch. A Pelton wheel, 6 feet in diameter is used, with a 2¾-inch nozzle, the wheel making 125 revolutions per min-



ELEVATION.



PLAN.

"PELTON WATER WHEEL USED IN THE WOONSOCKET ROLLER MILL. BUILT BY THE PELTON WATER WHEEL COMPANY, SAN FRANCISCO, CAL., U. S. A.

ute. The power is sufficient to run the mill with 40 barrels capacity, and also to operate an elevator raising 500 bushels of wheat per hour, to shell 100 bushels of corn and grind 4000 pounds of feed per hour. The cost of the well was $4000, or about £800. Splendid systems of water supply also are maintained by these wells. The water is pure and free from organic contamination.

The pipe generally used in putting down these wells is of the standard drive kind, though spiral riveted pipe is sometimes employed. An outside casing is first sunk and firmly seated on the rock, below all sand and quick sands, then a smaller size pipe is sunk inside the first,

THE FAMOUS WOONSOCKET WELL IN SOUTH DAKOTA, U. S. A. DEPTH, 775 FEET; DIAMETER, 7 INCHES.

the latter being carried to the bottom. The outer pipe is then pulled out, leaving a continuous pipe from top to bottom. The bore into the cap rock is generally of such size that the casing fits snugly, in order to prevent the water from working up around the outside of the pipe, and thus cutting the cap rock away.

All pipe used within the first or outside casing is held to the top of the well and is then securely jointed to the outer pipe. This is the safest expedient. The wells thus carefully constructed do not show signs of trouble, but where the work has been faulty, the wells have caused no end of trouble and destruction of property. It must be borne in mind that the Dakota sand stone varies greatly in its nature. In some places it seems little more than loose sand, while in other localities it is quite hard and compact.

The famous well at Chamberlain, which had attracted so much attention by reason of its immense flow of water, is now practically ruined. From the beginning, water escaped on the outside of the 8-inch pipe, and at one time threatened to engulf the roller mill which stands near by. The well has been an elephant on the hands of its owner from the first. While constructing a tunnel from the well to the Missouri river to carry away the surplus water, the tunnel caved in, killing one man, and another escaped only by a miracle. Efforts have been made at various times to stop the leaks on the outside of the pipe, but without success.

Recently a well contractor was employed to clear the pipe of rocks and other obstructions that had lodged in it. While engaged in doing this, the discovery was made that the pipe had parted. It is a distance of 50 feet down to chalk rock from the surface of the ground; then comes a layer of chalk rock 100 feet in thickness. Immediately under the chalk rock is where the pipe parted, leaving a gap of about 40 feet between the upper and lower sections of the disjointed casing. The well is certainly in a bad condition, and as the flow of water exceeds 4500 gallons per minute, it will give an idea of what a difficult task it would be to effectually control it. Efforts looking to this end have been abandoned, and the well, in the long struggle for its subjection, will be permitted to flow without molestation and interruption. In accordance with the decision to abandon further attempts to control the well, the mill has been shut down and will be moved from the locality.

Some of the most noted wells throw out more or less mud, sand and rocks of considerable size, to such an extent as to choke the pipe in some cases. This difficulty has been overcome to a great extent by dropping several lengths of perforated pipe to the bottom of the well, as shown in the little sketch on page 549. The pipe, inserted in this way, is perforated with holes, about three inches long and one inch across. This prevents larger bodies from gaining an entrance. The consequence of shutting off free access is that larger quantities of loose rock accumulate at the base of the pipe, as shown, and this, in some cases, has weakened the flow of the wells.

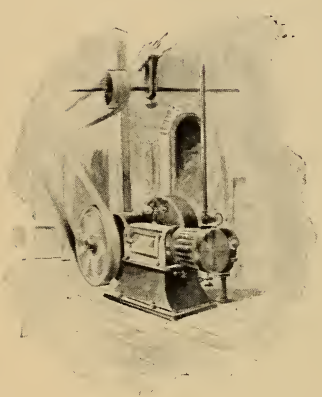
It frequently happens that waters carry internal evidence that betrays their origin. It was hoped that the analysis made in recent investigation by the United States government chemist at the Brookings, South Dakota Experiment Station, might tend to throw some light upon the origin of the waters underlying the great Dakota basin. Whether any progress in that direction could be made or not, would, naturally enough, depend much upon the rocks conveying the waters from their source to the points where they are delivered. If the rocks contain but little or no soluble substances, the problem would not be difficult to determine. If, on the other hand, the rocks through which the waters pass are charged with the same substances which the water carries before entering them, the problem would present greater difficulties. But even in the latter case the waters themselves might furnish evidences which might determine pretty accurately the direction which the underground current or movement assumes.

ANOTHER VIEW OF THE YANKTON WELL.

The preponderance of physical and geological evidence furnished by the expert chemists at Brookings points to the outcrops of the Dakota sand stone lying along the foot hills of the Rocky Mountains and to the outcrops of the same sand stone around the Black Hills, as the point of entrance of the waters in question, and it is more than probable that the waters of the melting snows in the mountains and the rainfall of large areas lying above these outcrops furnish the great artesian supply.

INSURANCE OF ENGINES.

By H. B. Spence.



THE nature of engine insurance is better understood in Lancashire than elsewhere, but even there, where engine insurance was born, and where it continues to make its home, it is by no means uncommon to meet well-informed men who are not acquainted with it. An engine policy is a contract by which an insurance company undertakes, in consideration for an annual premium, to make good the damage to an engine due to breakdown. The term "breakdown" is defined by the policy as the total or partial fracture of any of the principal parts of an engine, causing its immediate stoppage, and necessitating repairs before it can again resume work. Usually, only the engine itself and the wheels on the crankshaft are covered by the insurance, but occasionally the driven wheel or pinion and its shaft are included by virtue of a special endorsement, which carries with it an addition to the ordinary premium.

The amounts usually insured range from £100 to £1000, occasionally reaching a higher figure in the case of exceptionally large engines. The annual premium is not a fixed percentage of the sum insured, but varies also, with the type and size of the engine. Those driving by spur gearing, for example, are charged considerably more than if they transmitted the power by belts or ropes. To give a very rough idea of the relation between the amount insured and the premium, it may be said that the latter is between 2 per cent. and 4 per cent. of the former. The premium also covers the cost of periodical inspection, which is made primarily in the interests of the insurance company. These inspections are, however, of considerable service to the engine owner, as a report, with copies of the indicator diagrams obtained from the engine, is sent in after each visit.

The system of insuring engines against breakdown has existed in England for about 20 years, and was originated by Mr. Robert Longridge, who, at the time, was chief engineer of the Boiler Insurance and Steam Power Company of Manchester. This company was formed in 1859 in order to undertake the insurance of boilers against explosion. From 1854 up to that date Mr. Longridge had been engineer to the Manchester Steam Users' Association, instituted, to quote its full title, "for the prevention of steam boiler explosions and for the attainment of economy in the application of steam." Since 1859 Mr. Lavington Fletcher has been the chief engineer of this association, which first undertook the sys-

tematic inspection of boilers and engines, and which has succeeded, in a large degree, in the objects set forth by its title.

In 1878, Mr. Robert Longridge, being hampered by the limited powers of the Boiler Insurance Company, formed the Engine and Boiler Insurance Company, now the Engine, Boiler and Employers' Liability Insurance Company, in order to have fuller scope for carrying out his ideas in regard to engine insurance. Mr. Michael Longridge became the chief engineer of the new company, a post he still occupies, his annual reports, commencing in 1880, being mines of valuable information. Mr. Charles Longridge was the chief engineer of the Boiler Insurance Company for a short time after his father's departure, and was succeeded by Mr. Niel McDougall, who, after 8 years of service, left the Boiler Insurance Company, and formed a new one, the British Steam Users' Insurance Society.

In addition to the three companies already named, two others, the National Boiler and General Insurance Company, and the Yorkshire Boiler Insurance and Steam Users' Company, also undertake the insurance of engines. All these companies, with the exception of the last named, have their headquarters in Manchester.

Considerable difference of opinion exists as to the advantages of engine insurance. That there are advantages to the insurer is almost universally acknowledged, at all events in the textile manufacturing districts, although all would by no means agree as regards the nature of such advantages. Some insure mainly for the sake of the examinations and reports made by the insurance company's officials. The value of periodical inspection by competent, independent engineers is apparent, when it is considered that a large number of land engines are in charge of men without much special mechanical training. In the case of those large mills or works, where there are trained engineers in charge of all the machinery, the owners naturally depend on their own men to a greater extent, but even in such cases it is useful to have independent reports. The compensation, too, received for breakdowns is not to be despised.

Occasionally it is urged that there is no need for insurance when an engine is of ample strength and very carefully looked after, while immunity from breakdowns in the past is also adduced as a reason for expecting similar fortune in the future. The experience of insurance companies, however, shows that the fortunate owner of such an engine owes as much to chance as to his own foresight. Engine insurance is fertile of surprises, and it is impossible entirely to prevent accidents.

In support of this argument, the table given below shows that one-third of the breakdowns which occur, are due to causes either entirely accidental, or not ascertained. These figures are from Mr. Michael Longridge's annual reports, already referred to, and represent the results of investigation into 1790 breakdowns, extending over a period of 14 years.

Causes of Breakdowns.

Purely accidental or unascertained	34 per cent.
Negligence of owners or attendants	19 per cent.
Old defects or wear and tear	18 per cent.
Weakness or faults in design or workmanship	29 per cent.

Of these four classes the last three are, at all events in some degree, preventable, and there is, consequently, quite sufficient margin for improvement to encourage those responsible for the care of engines, in endeavouring to reduce the risk of breakdown. "Trifles make up perfection," is a true, if a trite, saying, and the history of many a breakdown is not unlike the story of the kingdom lost "for the want of a horse-shoe nail."

Engine owners and attendants are too apt to assume that because an engine is doing its work well, it is in satisfactory order throughout, and consequently it would only be tempting Providence to disturb the working parts. Many accidents would have been prevented by timely examination but for this unwise confidence. It is by no means uncommon for a large engine to work for two or even three

years without any examination of the crankshaft journals, the reason usually given for such neglect being the fear of the bearings heating after being opened up. In the course of a couple of years a defect may develop and may actually cause fracture of the shaft and serious damage, without any warning being given. On the other hand, if examinations are made more frequently, the defect will almost certainly be discovered in its earlier stage, and stoppage of the works can be avoided by having a new shaft prepared, while the defective one is still at work.

When all the working parts of an engine are opened up periodically, the risk of trouble from heating or like causes on resuming work is much less than when such examinations are only made at very long intervals. The principal bearings, crankshaft, crankpins, crossheads, should be examined about twice a year, and the interior of cylinders, pistons, valves and air pumps should be seen about every 3 months.

The chief problems which have presented themselves to the insurance engineers for solution have been, first, to ascertain as exactly as possible, the cause of each breakdown ; and second, to point out how such accidents can be avoided in the future. In their treatment of these questions, the engineers, and noticeably Mr. Michael Longridge, have rendered their most valuable services to both makers and users of engines, and it is to be regretted that the results of their labours in this direction are not still more widely known.

It may be useful to sum up briefly the general results of these enquiries, and in doing so the various classes of breakdowns and their relative importance will first be mentioned. Each class will then be considered separately, the most common causes of breakdown and the remedies available being indicated as far as possible. Among the parts of an engine which by their breakdown involve insurance companies in the heaviest expense, spur driving wheels take a first place. According to Mr. Longridge's reports, nearly 20 per cent. of the breakdowns of engines insured with his company during the last 14 years have been failures of spur gearing. The average cost of repairs in these cases is considerably above the average of all claims, and it is probably not too much to say that accidents to spur gearing account for about 40 per cent. of the total amount paid by the insurance companies as compensation for engine breakdowns. It must also be remembered that the sum received from an insurance company by no means covers the loss occasioned to the engine owner by a breakdown. What may be termed "consequential damages," the largest item in which is the loss occasioned by the stoppage of the works and manufacture, sometimes considerably exceed the amount of the insurance company's liability.

Breakdowns of crankshafts and of cylinders, pistons, etc., come next in importance, while air pumps and valve gear are each responsible for nearly as many breakdowns as spur gearing. The two last classes of accident, though numerous, are not usually costly in repairs, and consequently do not bulk largely in the companies' analyses of claims, although they are the cause of very serious trouble and annoyance to the engine owner, as each failure means a stoppage of his works, sometimes of considerable duration.

Perhaps the most common cause of the breakdown of spur wheels is "backlash." In many cases, particularly of old wheels, excessive clearance exists between the teeth. This defect, associated, as it usually is in old engines, with a light fly-wheel, causes a heavy knock in the teeth twice or sometimes four times in a revolution. This means that, in the case of an engine running at say 30 revolutions per minute for 10 hours each day, the teeth would be subjected to 36,000, or possibly 72,000, blows every day. No great effort of the imagination is required to picture the result of such rough usage. Unfortunately there is a somewhat general tendency to regard "backlash" as an evil inseparable from spur gearing, and in consequence all is not done that might be to remove the defect. The

frequent breakages of one or more teeth can usually be traced to this cause, and the most serious breakdowns of spur wheels are often caused by a single tooth breaking and falling between the wheels.

Other common causes are the condition of foundations under the main pedestals; a long and weak form of tooth; and the slackening or fracture of the keys or bolts holding the parts of a wheel together. Bolts are to be preferred to keys, as they are less dependent on hand fitting for their security. They should always be fitted with locknuts, and should all be accessible, so that they can be tried from time to time. One caution is, however, necessary with regard to the use of bolts,—the leverage and force used in tightening them should be kept within reasonable bounds, as bolts are sometimes overstrained from this cause before their ordinary working load comes upon them.

Mr. Longridge's records, which are here referred to so frequently, on account of the recognized care and ability of their compiler and because they extend over a longer period than other available figures, show that failures of main crankshafts number 87 out of 1790 breakdowns, recorded up to the end of 1893. The proportion is only about 5 per cent. of the total number of accidents, but the percentage does not represent the importance of this class of breakdown, as many of the fractured shafts must have given considerable trouble before actually being replaced. The claims are also considerably above the average in amount. Over 80 per cent. of the broken shafts were of wrought iron and of the remainder nearly all were of Bessemer steel. Early in the history of steel shafts, the untrustworthiness of steel made by the Bessemer process was clearly shown, but failures of shafts of Siemens-Martin or open-hearth steel are of very rare occurrence.

The mode of making wrought-iron shafts by faggotting bars and working them under the hammer is incapable of producing a homogeneous shaft. Some of the numerous internal welds are sure to be more or less imperfect, and thus every wrought-iron shaft carries within itself the seeds of dissolution. Any one of these internal defects may, in course of time, develop into a dangerous flaw, the process being hastened by the constant changes in the direction of the stresses when at work, and also by over-heating.

Longitudinal fractures are of most frequent occurrence in wrought-iron shafts, but are often of slight importance. As a rule, they extend gradually and their progress can be watched. If a flaw extends circumferentially, however, immediate steps should be taken to ascertain its depth. This can often be done by drilling until either the bottom of the crack is reached or until it is evident that it is sufficiently deep to be immediately dangerous.

In the case of steel shafts, it is of the first importance to get them from steel makers of the highest reputation. If due care be taken in selecting the material, there is no doubt that a mild steel shaft is safer and more trustworthy than a wrought-iron one containing 20 per cent. more material. It may be thought that there is scarcely need, now-a-days, to insist on the superiority of steel. There is, however, a fairly numerous class of engine owners (and even a few engine builders) who have a lingering fondness for wrought-iron shafts, chiefly on account of the comparatively gradual development of defects in that material. Mild steel shafts, as now made, are, however, of such uniform and high quality that this argument has lost its force.

Many breakdowns of cylinders, pistons and piston rods are caused by water in the cylinder. The presence of water is due, sometimes, to priming, occasionally to an overflow from the condenser when the engine is at rest, but most frequently to condensation on the admission of steam to a cold cylinder when starting the engine. Properly fitted escape valves would prevent accidents in many cases, and the risk is also less in jacketed cylinders, if care be taken to warm up the cylinder thoroughly before starting. In most

cases, however, carelessness of the attendant, is altogether, or in part, the cause.

Numerous accidents of this class are caused by defective piston rings, loose or defective piston screws and defective crosshead or piston cotters. In one instance, the rings of the high-pressure piston of a large pair of mill engines, were found broken into small pieces when the cylinder was opened up. Each fragment was so worn and rounded that it was evident the rings had been broken for some time, and it was little short of a miracle that a serious breakdown had not occurred. All the causes just named should not, of course, be possible under careful supervision; but human nature is fallible. The risk is lessened by the use of nuts, instead of cotters, at both ends of the piston rods.

In this particular, marine practice has the advantage, as the cotter is rarely used at sea; but there are still many land engine builders of high standing, who use the cotter as a fastening for piston and connecting rods, in preference to the nut. In land engines, fracture of the piston rod through the cotter hole is of frequent occurrence, and is often due to defective fittings of the cotter. In another detail which affects safety, marine engines are better furnished, and that is in securing the piston screws. This is scarcely ever done in the case of land engines, in spite of the fact that accidents caused by loose or broken screws of this kind are of not infrequent occurrence.

The behaviour of air pumps is often very perplexing to engineers, and in consequence it is sometimes difficult to trace the cause of breakdowns in these parts. The most frequent cause is probably defective bucket rings, and the remedy, strongly advocated by Mr. Longridge, is to use a plain, deep, grooved bucket without any packing rings. Such buckets are found to answer admirably and do away with one source of trouble. Simplicity of working gear and frequent inspection will also do much to keep down the number of failures.

The numerous breakdowns of valves and valve gear are, to a large extent, preventable. The remedies are simple and strong gear, sufficiency of wearing surface, efficient lubrication and careful, frequent examination.

As to the contributions of engineering insurance to the science of steam engineering, it has become generally recognized that in regard to boilers, the Manchester Steam Users' Association and the boiler insurance companies have rendered valuable services to all users of steam, and to engineers generally. By their system of inspection, investigations and experiments, they have added largely to the general stock of knowledge, and done much to reduce the number of explosions. Compared with all this, it must be conceded at once that no achievements so striking can be recorded in the department of engine insurance. Loss of life through engine breakdowns is fortunately of very rare occurrence, and in consequence, recommendations affecting the safety of an engine have not the same force as in the case of a boiler. Still the engine insurance companies, through their engineers, have certainly been, to a large extent, instrumental in bringing about considerable improvements both in economy of working and in the design of steam engines. In support of the first part of this statement, it should be mentioned that in 1880 the first complete and thorough trial of a large mill engine was made by Mr. Michael Longridge, of the Engine and Boiler Insurance Company, the results being published in an appendix to his 1880 report. Since then both Mr. Longridge and Mr. McDougall have carried out numerous similar trials, the results of which have been valuable as providing accurate data for calculations concerning steam engine performances.

Several alterations in design, now generally regarded as improvements, have been brought about mainly by the efforts of insurance engineers, often in the face of considerable opposition on the part of engine builders. Among such alterations may be mentioned the fitting of escape valves to cylinders and valve chests; the provision of fillets

where changes of diameter occur in shafts, crankpins and gudgeons; and the disuse of packing rings in air pump buckets. In the substitution of steel for wrought iron, and of ropes for spur gearing, the influence of the insurance engineers has been actively used, and Mr. Longridge's advocacy of very short teeth for spur wheels has modified the former usual proportions in a marked degree.

In conclusion, a few words may be devoted to the relations which exist between insurer and insured. As a rule, these relations are pleasant enough, although disputes regarding the settlement of breakdown claims are not unknown. The ordinary caution of some business men is inclined to deepen into suspicion when they have to deal with insurance companies, and the natural consequence is that the latter do not feel disposed to go beyond the actual letter of their contract.

THE RECORDING GAUGE.

Applied to Water Pressure and Other Uses.

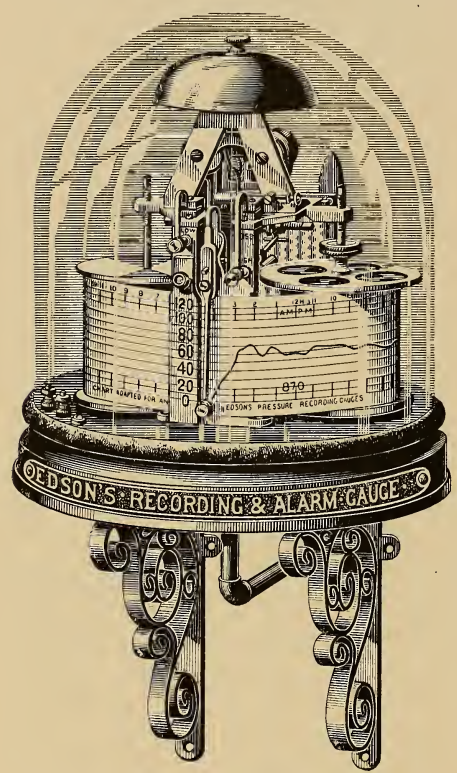
By Charles A. Hague.

THE article treating of recording pressure gauges, which appeared in the September number of CASSIER'S MAGAZINE, relating chiefly to the application of such gauges to steam pressure, formed one portion of a subject which was found to be too extended to be contained within the ordinary limits of a single contribution; hence, the continuation of the subject in a different line from that previously followed. Before entering upon this new branch of the matter, however, it is thought best to present a description of the instrument, and in selecting one for this purpose, the writer turns, first, to one of the longest and best known of all those in the market, viz., the Edson gauge, shown on the following pages.

This gauge consists of a metal base or pedestal, A, enclosing beneath it a tempered, corrugated, steel diaphragm, C, which forms the spring of the instrument, and the resilience of this form of steel spring under long usage and heavy pressure is, to say the least, remarkable. This arrangement is such that when the fluid under pressure enters the space D between the spring and the cap E, forming the chamber, the spring is deflected upwardly, corresponding to the degree of force exerted against its under surface. The mechanism composing the recording portion of the instrument, is mounted upon the top of the pedestal A, and the movement of the corrugated disk C is transmitted through the levers H^2 and H^3, on the rock shaft H, by means of the connecting rod G, to the vertically moving pencil holder in front, the pencil being thus moved through a distance approximately six times the original travel of the spring at its point of contact with the pencil movement.

Clockwork, specially designed and adapted for the purpose, revolves the receiving reel K^2, and draws the paper forming the chart by means of this motion beneath the recording pencil. The motion of the clockwork, of course, corresponds to the hours of the day and

night. The records of time and pressure being represented by rectangular ordinates, the record may be read at a glance, and the tendency of a change of pressure can be fully and quickly comprehended. Ordinarily, the reel K holds sufficient paper to form a chart extending over thirty days, but the



RECORDING GAUGE MADE BY J. B. EDSON, NEW YORK.

extent used for each day may be removed at pleasure.

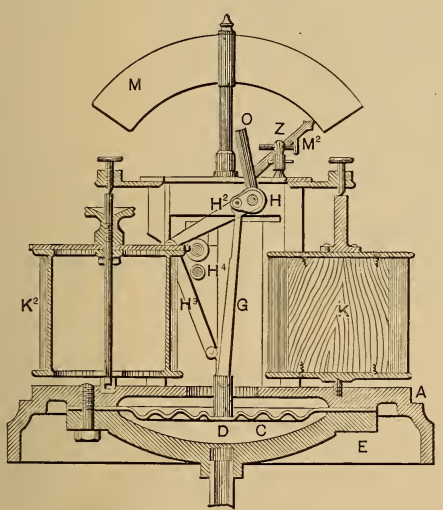
The adjustable arm O, when applied to the gauge, acts as a circuit closer for an electro-magnetic alarm, and operates a mechanical alarm usually provided with the instrument. The index Z and index plate M are not used in the latest form of this gauge. A dome of glass, resting upon the edge of the pedestal A, protects the whole from injury or interference, dust or moisture. If it be not convenient or desirable to change records every day, the chart may be allowed to run continuously for any length of time within thirty days and with separate bells for announcing either the high or low limit of the range of pressure that it has been determined upon to carry. The motion of the pencil mechanism is practically, and, indeed, well-nigh absolutely, steady and without quiver, other than that of the fluid, for the reason that the friction of the pencil movement sinks into insignificance, compared with the force represented by the gross pressure against the diaphragm and the resistance of the spring.

Another form of recording gauge, comparatively new, but beginning to be well known, is the Bristol gauge. This gauge consists of a pressure tube with an inking pointer attached thereto. The pressure enters the sinuous tube A, which tends to straighten and elongate the tube. This tendency to straighten, upon the part of the tube, is resisted by a flexible strip, B, which is joined to the bends of the tube A, thereby converting the tendency to elongate into a multiplied lateral motion. The inking pointer is attached to the end of the pressure tube, and thus records the fluctuations of pressure upon a circular chart, revolved, by means of clockwork, at the rate of speed exactly corresponding to the 24 hours in one day. This chart, making one revolution in the 24 hours, is marked off with radial arcs, and concentric circles. The divisions upon the radial arcs correspond to differences in pressure, while those on the concentric circles correspond to the hours of the day. Each circular chart, therefore, represents 24 hours of service of the gauge, and is replaced by a fresh one every day.

In considering the application of the recording gauge to water pressures, a field of usefulness, probably second to none, is that of water supply and distribution in public service. For in this, not only is the generation and use of steam involved, but also the pumping and furnishing of the water under pressure, the energy developed, and the useful work accomplished by the machinery in use, being, in pumping plants,

reckoned in terms based upon force. The power employed, and the results produced, are alike brought within the impartial jurisdiction of the record chart.

Water works service in cities may be separated into two grand divisions,—one in which the pressure in the mains is supposed to be constant, and the other in which the pressure is held at a certain point for domestic supply, and is increased in case of fire. In either case, absolute uniformity of water pressure under any certain conditions aimed at, is to be desired and secured as closely as possible. In gravity works, of course, the friction in pipes, as set forth by the relation between supply and demand, is the principal disturbing element. A recording gauge attached to the mains leading to any particular district would be fully competent to show, in a short time, whether the pipes are large enough or not, or to locate any trouble in the shape of water hammer, or in the matter of obstruction to flow, from whatever cause.



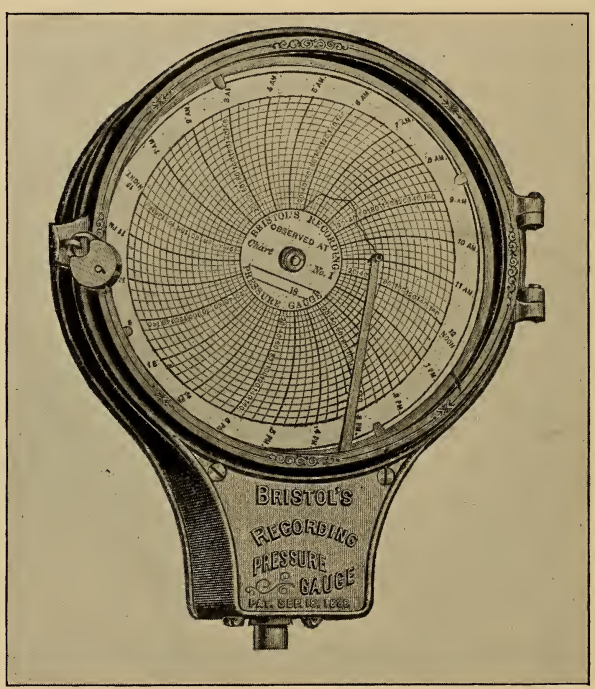
SECTIONAL VIEW OF THE EDSON GAUGE.

Where pumping machinery is depended upon in part or entirely, it is not too strong an assertion to say that the gauge is indispensable for the best, or even good, results, the chart showing the water pressure as it has been during the hours that it was on duty. Fluctuations in pressure to any amount, and from any cause, are faithfully portrayed; whether usual or unusual, they are detected at once. Any failure in fire service, giving rise to disputes as to pressure, time, etc., can be located, and the disputes settled by simply referring to this most impartial of monitors. The chart would show the precise moment at which the pressure was increased in response to the fire alarm, how long and how steadily it was maintained, and when it was reduced again to domestic requirements. Fires sometimes occur on lines of pipe far from the pumping station, and although the record shows a prompt compliance with the sounding of the alarm, not to be disputed, the failure to get efficient fire streams indicates clearly that either some obstruction intervenes, or else the pipes are not of sufficient capacity between the source of supply and the point at which the fire service is needed.

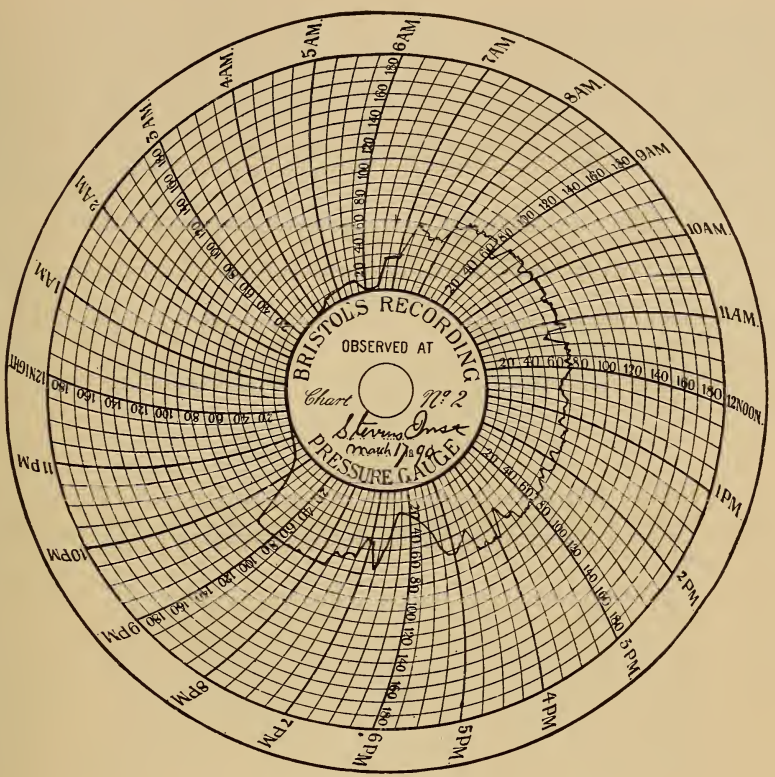
This condition of overdraught of water for fire service in a given section is exactly what occurred several years ago at a large fire, and which resulted in a very much greater loss of property than would have occurred had the fire engines been able to get all they required and could handle. What has since been done, viz.: the placing of an additional feeder to the section involved, might have been done before, and would have been done, had records of pressure been regularly made whenever a fire occurred in that vicinity, showing how easy it was to draw the head down below a safe and prudent point. Sometimes too many fire streams are attempted where the supply of water in the mains is limited, and instead of a few good ones, double the number of bad ones are used. A fire stream must be aggressive, and go in force just where it is wanted. The floors are generally the last places that burn in a building, and water just spilled in upon the floors does not do much direct good, but only in a secondary manner; whereas a stream, with a dash to it, and able to go searching up under the ceilings and among timbers, will be pretty apt to be of some material service.

Upon one occasion, coming to the writer's knowledge, where a part of the water supply was pumped by water-power, and where, in case of fire, the extra quantity was delivered by starting additional turbines, the fire department was somewhat tardy, and the fire obtained such headway that a great amount of damage was done that should have been averted. An investigation of the facts proved, by the chart from the recording gauge, that the water increased in pressure at the pump house immediately upon the fire alarm signal, notwithstanding that the fire companies all testified that they were on hand within a few minutes, and that there was no pressure. The superintendent of the water works would have lost his position under extremely unjust conditions had he not been able to produce his record; and the multitude of witnesses who declared that there was no pressure would have overcome the facts, the truth and the engineer's statement.

In a certain city, politics interfered, as it sometimes will, with the efficiency of the water department, and it was determined to oust the superintendent, because he had been too active to suit the "outs." By pre-arrangement some of the firemen placed bundles of stones and gravel in the hose pipes, and, of course, the flow of water, at the next fire, was very much curtailed; in fact, the streams of water appeared to be so feeble that some of the citizens became alarmed in watching the headway the fire was making, and went hurriedly to the pumping station, only to find by the recording gauge that the fire pressure had been promptly run up, and properly maintained without a moment's loss of time. This fact established, the "boys" took opportunity to clear out the hose-pipes one by one without being caught at it. Detectives sub-



RECORDING GAUGE MADE BY THE BRISTOL COMPANY, WATERBURY, CONN., U. S. A.



A BRISTOL GAUGE CHART.

sequently arrived at the facts as above stated.

Of course, all realize the seriousness and importance of the fire service, and many can, no doubt, recall incidents and accidents, wherein nobody knew exactly what did happen, or how it happened. It was only known that at some vital moment or other the water pressure failed. How far from the hydrants the failure extended no one could tell. The pumping station people declared that the pressure was all right where they were, but even they had no evidence beyond their unsupported assertions. Sometimes changes and extensions in the distributing mains have been made, and the powers that be dwell in fancied security, when suddenly the call of danger comes and they find, to their sorrow, that some conditions existed, of which they were not aware, and which cost somebody a goodly sum of money. After this, such remedies are quietly applied as a darkened state of information could conceive of as necessary to meet the case.

The pressure of water required at the nozzle of a hose pipe is not very great, but it must be borne in mind that every foot of hose between the hose pipe and the hydrant or fire engine, demands tribute in the shape of friction from the onrushing stream. Where steam fire engines are used, the pressure necessary to overcome the friction in the hose, may be regulated to suit the length used, delivering the water at the nozzle with the desired force; but where direct hydrant pressure is used, every foot of hose reduces the force, without any chance for renewing it, and the working effect at the nozzle is very uncertain.

In a certain city a neighbour of one of the water company's officers suffered

a fire loss at his residence, and meeting said officer, complained that if there had been a little more water pressure the fire could have been extinguished at its early stage with the use of the garden hose. The official expostulated at the idea of the pressure not being sufficient to supply a garden hose; but when, a little later on, his own coach-

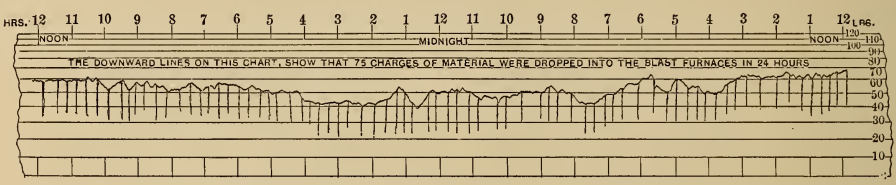


FIG. I. AN EDSON GAUGE CHART FROM A STEEL WORKS.

man complained, for the second time, that the water would not run in sufficient quantities to enable him to wash the carriages, our official friend was induced to attach a recording gauge at an appropriate point in the neighbourhood, and, to his surprise and alarm, discovered that at times the water pressure fell just about to zero. This had, no doubt, happened many times, and just happened at the time a small fire broke out, with the result of a serious loss. An investigation, during which the re-

in the United States, says in one of his annual reports:—"No well-conducted water works can afford to be without recording gauges, and when properly located, they will, in my opinion, pay for themselves within one year. We challenge any water works in the United States to play 70 one-inch fire streams through fifty feet of hose and maintain eighty pounds pressure during the trial, the pressure to be verified by recording gauges, placed at suitable positions on the line of pipe."

This completeness of distribution is the result of observations and experiments with the use of recorders, and the gradual elimination of restricted points of flow, dead ends, etc. The presence of water hammer, oscillation in the water column, and other abnormal conditions, caused, perhaps, by dead ends or faulty circulation, will be

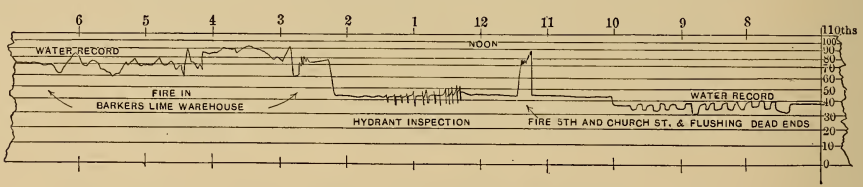


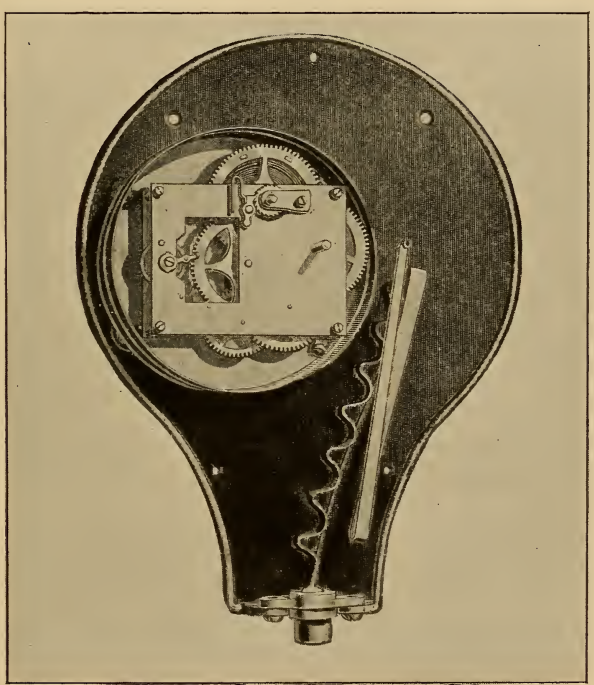
FIG. 2. AN EDSON WATER WORKS CHART.

corder was applied to various points on mains leading to the district in question, pointed out the way of remedying the trouble; and a paltry expenditure for cross-connections from a larger main, not far away, gave an increased, and very much more continuous, pressure, entirely removing all danger of a repetition of the previous discrepancy.

Bearing upon this particular point, Mr. Edwin Darling, superintendent of the Pawtucket (R. I.) Water Works, indicated beyond mistake by the sharp and sudden rising of the telltale pencil. The sudden fluctuation of water pressure in the pipes of a water works system can not be too carefully guarded against, as it means leakage of joints, waste of water, repairs and loss. It must be easy to perceive that a net work of pipes connected in every direction, and of reasonable capacity, will prevent any sudden or rapid flow or rush of water in response to a heavy

draught at a single, or concentrated points; and, of course, the less rapid the flow, and the more chances for reaction in other directions, the nearer normal the conditions will be retained under circumstances tending to disturbance. The water wasted costs just as much to pump and distribute as the water used.

The writer has in mind a water works plant, upon the reservoir plan, under a pressure of 120 pounds, in the lower portion of a city, where numerous house boilers commenced to give out that up to a certain day had seemed strong enough. After considerable damage had been done during two or three weeks, it was discovered that the trouble was caused by water ram, the result of a connection having been made for the supplying of locomotives, a 6-inch globe valve being opened wide as quickly as possible, from one to two thousand gallons of water emptied into the locomotive tank at the shortest possible notice, and then the valve closed very rapidly when the tank was filled. The application of an ordinary water pressure gauge from a steam fire engine, graduated up to 300 pounds, and closely watched for several hours, developed the fact that the static head produced a pressure of 120 pounds at the point of draught, and also at a point in the distribution about 2000 feet from the point of draught. When an engine tank was being filled through a wide-open 6-inch valve, the water pressure fell to 85 pounds; and when the valve was quickly closed, as it always was, the reaction upon the water column ran the pressure considerably past the 300-pound mark upon the gauge. After five or six vibrations, from just below 100 up to more than 200, the motion gradually decreasing, the pressure finally settled down steadily at 120 again. A smaller outlet, an air chamber, and a safety valve, cured the trouble after it had been located. A good recording



THE MECHANISM OF THE BRISTOL GAUGE.

gauge would have rung an alarm and disclosed the excessive pressure the first time it occurred, thereby saving many times its cost.

Innumerable instances might be cited, but they would exhibit only the surprisingly large number of unforeseen and unsuspected occurrences, possible in a system of pipes laid in the streets of a city for water works purposes.

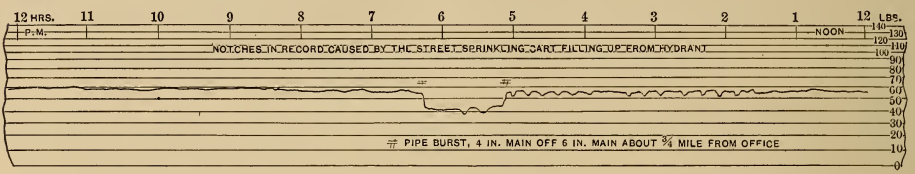

12 HRS. 11 10 9 8 7 6 5 4 3 2 1 12 LBS.
P.M. NOON
NOTCHES IN RECORD CAUSED BY THE STREET SPRINKLING CART FILLING UP FROM HYDRANT
PIPE BURST, 4 IN. MAIN OFF 6 IN. MAIN ABOUT ¾ MILE FROM OFFICE

FIG. 3. AN EDSON WATER WORKS CHART, INDICATING THE PERIODICAL FILLING OF STREET SPRINKLING CARTS

Fig. 1 on page 564 shows a 24-hour chart, taken from an Edson gauge, which was attached to the water supply pipe, entering the works of a well-known steel company. It cannot fail to awaken the interest of all concerned in such plants, to observe the fidelity with which the different charges of material are recorded. Aside from the general fluctuations in water pressure, caused by a more or less steady draught of water both inside and outside of the plant, near enough to the point of attachment of the gauge to make itself felt, the absolute certainty of the response of the pencil whenever the hy-

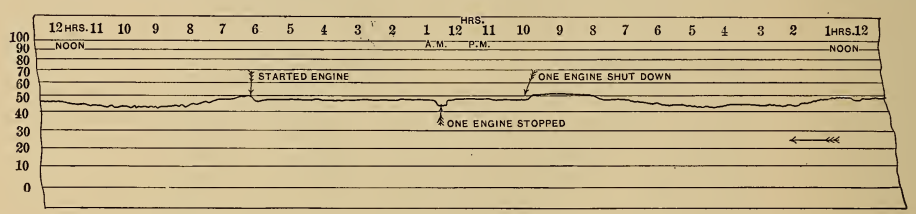


FIG. 4. ANOTHER WATER WORKS CHART, INDICATING THE STARTING AND STOPPING OF PUMPING ENGINES.

The ordinary gauge drops away and then comes back to the normal pressure, or raises and returns again to the regular point. But who sees it? It goes through the same fluctuations as the recording gauge, but who can read it, or realize what it means, until the results are graphically delineated upon a chart, divided off to suit the hours of the day and night, even exhibiting when and for how long each sprinkling cart

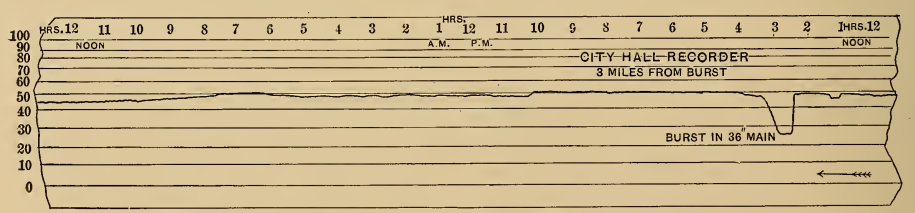


FIG. 5. CHART SHOWING THE BURSTING OF A WATER MAIN.

draulic elevator carried a charge of material up to the platform, is, to say the least, gratifying to see.

Each horizontally numbered division of the chart being an hour in extent, the few minutes required for the upward passage of the elevator, only resulted in a downward and an upward line almost coincident with each other. Imagine the satisfaction and convenience to the manager, or superintendent, in contemplating the certainty with which he can know how things are going, or have gone.

Some years ago, in fitting up a large foundry, the writer had an oppartunity of arranging the charging of the cupolas under just such conditions as above, and the records of experiments in actual foundry work with different kinds of stock, different times of charging, quantities and qualities of fuels, various mixtures of iron, etc., were very useful. Among other experiments, it is distinctly remembered that in trying for an appropriate mixture of scrap cast steel, with Lake Superior and Scotch pig, for some large drop-press dies for heavy forming and welding work, the elements of frequency and regularity were invaluable; and the best mixtures, handled in the best manner at the cupola, were completely kept track of with the recording chart as a basis. Of course, some man could have kept a record in a book, but in this case the elevator and the recording gauge took charge of matters, and made a clear, plain statement as far as the times of charging were concerned; and this being so unequivocal, lent a spirit of certainty to the entire transaction. With the same mixtures weighed out, it was found that a varying interval in charging the steel, made considerable variation in the practical value of the castings, not only under the tools in fitting up the dies, but also in the durability of the faces of the dies under the impact of forging, bending and welding.

Fig. 2 is a chart from a water works plant in which the direct system of pumping supply is employed. Beginning at about 7 A. M., the chart shows the regular or domestic pressure; at 7.30, the work of flushing out some "dead ends" and hydrants was commenced, and was continued until nearly 10 o'clock, when the regular pressure was again steadily resumed. At 11.15 of the same forenoon, a fire alarm called for the pressure to be raised from about 40 lbs. to 90 lbs. At 11.30 the pressure was again dropped to from 40 to 50 lbs. At 12.20 an inspection of fire hydrants took place, lasting until 1.30. At 2.10 P. M. another fire alarm sent the pressure up to 80 lbs., and fluctuating between 95 and 70, according to the variations in the use of the water as the fire progressed. The pressure was maintained at fire service, sometime after 7 P. M., beyond which point the section of the chart does not continue, it having been torn off so as to bring it within magazine page limits.

Fig. 3 is also from a water works system. Beginning about 1.30 P. M., the notches shown indicate the filling of the street sprinkling carts at different times until 5 P. M., when a 4-inch pipe, from which the water carts had been drawing water, burst. The result upon the pressure is clearly shown. Over an hour elapsed before the outflow was stopped, which, although not speaking very favourably for those in authority, most certainly indicates just what happened, and at what time the event took place. It is very curious, not to say amusing, to note that two sprinkling carts endeavoured to fill under the reduced pressure during the time that the break was letting the water run to waste; and probably more would have tried, but for the fact that 6 P. M. was at hand, as is clearly shown by the record. About 6.20 P. M. the loss of water was checked, and then, as the evening wore on, and the use of water gradually slackened, the pressure very slowly crept upwards, until at midnight the record showed 70 lbs.

Figs. 4 and 5, illustrate from actual charts the breaking of a 36-inch main, the starting and stopping of pumping engines and the daily routine already mentioned. The point in the record, between midnight and 1 A. M., shows when an engine stopped accidentally;

and the loss of pumpage being greater than the current demand could sustain, the water pressure promptly fell away about 5 lbs., until the engine was again started, when it as readily recorded its normal point.

A loss of pressure is sometimes indicative of as much or more danger or loss, as an over-pressure, and it is just as important to learn of it promptly. A case is recalled of a washout which occurred during a rainy night, and opened one of the joints of the force main where its embankment was exposed near a deep ravine. The water pressure was reduced so much and so suddenly, that the low pressure electric alarm sounded, calling attention to the great loss of pressure and leading to the discovery of an enormous leak in the line. The superintendent was enabled to locate and remedy the accident before extensive damage had been done by the escaping water, to say nothing of the danger and lack of water in case of fire during the very much longer time that would, in all probability, have elapsed under other conditions.

Another case is that of a gravity supply in a moderate-sized city, which, becoming insufficient, was supplemented by the boring of wells and furnishing of pumping machinery. Some time after completion of the auxiliary works, one of the large manufacturers of the place had occasion to overhaul a turbine wheel pit, and in so doing, encountered what was considered to be a large and copious spring. After exploration and examination it was discovered that the supposed spring could only be stopped when the 10-inch main delivering water to that section was shut off; and when this unexpected and previously unknown leak was repaired, the new wells and machinery were not needed. Carefully noted record charts, in this case, consulted at regular intervals during the period of complaints which led to the extension of the works, would most undoubtedly have developed facts that would have saved the unnecessary addition.

The writer has for many years observed the construction, operation and extension of water works plants for public supply, and he has arrived at the conclusion that the great importance of a continuous, complete knowledge of the pressure maintained throughout every part of a water works system is in the interest of water works companies, cities, taxpayers and fire underwriters; in the interest of health; in the interest of safety.

In laying out, or in extending a system of pipes, care is taken, of course, to so proportion and arrange them as to give the most efficient distribution for domestic, manufacturing and fire service; and as each case is peculiar to itself, according to the area of section to be supplied, general levels and special conditions, the success of the undertaking is, more or less, in the nature of things, problematical, and not to be exactly determined until the works are in operation. Further, even when the construction and distribution are practically correct to meet the conditions originally imposed, the growth of cities presented a constant necessity for change and readjustment. One portion of a city or village, will, although unforeseen, be found to be possessed of desirable features as a manufacturing centre, thus increasing the demand for water, both for domestic and fire service, entirely beyond any extent looked for when the plant was devised. Such a state of affairs, in the absence of records, will be most certain to bring us very readily and suddenly, at sometime or other, in contact with the disagreeable and dangerous fact that the distribution of water is entirely inadequate to meet the demands. In another section of a city, perhaps limited to comparatively a few squares, the commercial and similar interests may become concentrated in lofty office buildings, while another portion of the city, quite remote, may be devoted to a thickly settled population. All such occurrences modify the efficiency, or reliability, of a water plant laid out with the idea of uniform distribution of water. We may not want uniform distribution, but, on the contrary, a very uneven disposal of the supply. One of the tall

buildings in some large city may need, eventually, an amount of water usually allotted to the population of a square mile; and those in charge of such buildings have long since found it necessary to so place their steam pumps as to enable them to draw all that the mains in their immediate vicinity can supply, regardless of the adjacent neighbors, who probably wonder where all the water is going, or has gone to.

If a certain number of gallons of water per capita, are essential to the health and comfort of a community, such can only be effective when properly distributed, and it can only be known that it is properly distributed, when it is known that sufficient pressure is available at the various points to deliver the required quantity of water. First, ascertain what is going on within the system, and the point at which any remedy is needed, and the manner of applying it will be suggested at once.

One of the most remarkable examples of the utility, value and practicability of pressure records in water works service, is exhibited in one large city, where, by their use, the distributing system is shown to have been brought up to a perfection which leaves very little to be desired. The losses of head in different directions from the pumping stations and reservoirs, considering the great extent of territory covered, are surprisingly small and uniform, indicating with perfect clearness that whatever the varying demands may be, whether in the manufacturing districts, where the demand is very great, or in the residence portion, where a comparatively thinly occupied area draws only what is needed for domestic use, the capacity of the distributing mains are properly proportioned to the work to be done. There is one recording gauge in the water commissioner's office in the town hall, about three miles from the principal pumping station, and so perfect is the circulation, that the starting or stopping of any of the pumping engines is clearly shown.

The day's history shown upon the chart is about as follows:—Soon after five in the morning, the gradual, but slight, fall of pressure from a horizontal line that has been maintained for several hours, indicates that the early risers are getting ready for breakfast. This fall in pressure goes on until about six, when an additional pumping engine is started, bringing the pressure back to normal, or a little above. About six thirty or seven o'clock, when the manufacturing concerns open up, the demands are clearly shown. Then the street sprinklers, taking water . near enough to the town hall to be felt, begin to indicate that they are drawing water; and so the line goes on throughout the day, clearly giving the history of that day's consumption.

Soon after six in the evening, the gradual rise of pressure attests the fact that the day's work is over, that too much water is being pumped, and after this is allowed to go on so as to bring up the reservoir to a normal level, at ten, or ten thirty, the slight drop in the line plainly gives notice that one of the engines has been shut down. If the pressure still continues to rise, another engine is stopped, and finally the pressure line runs along through the night hours nearly or quite uniform. If a night fire threatens too much loss of head, the machinery is put in motion again, and the loss made good. The stoppage of an engine in the night, either from intent, accident or carelessness, is plainly marked; also the time which elapsed before that or another engine was started again. The water commissioner has a habit of looking over the chart each day, and before the people at the pumping stations understood how on earth the commissioner came to be so well posted, he occasionally astonished them by quietly dropping in and asking "the cause of the stoppage of engine No. 3 last night."

In the same city one of the 36-inch mains burst, about half a mile from the pumping station, and two and a half miles from the town hall recording gauge. The break occurred about half-past two on a Sunday afternoon, and no one could have known, without a continuous record, that there was no water hammer indicated just before the

break, and its cause would have been enveloped in mystery a good deal deeper than it was, if the gauge had not shown with perfect accuracy that two or three reasons at least, which a man in the dark would have given, did not exist. The steady line usually shown on Sunday suddenly dropped nearly in a vertical direction, then it continued upon the lower level for about half an hour, until the men at the pumping station, who had received the alarm, had arrived at the nearest shut-off gates, and began to close off the broken section. Then the gradually rising line, indicating how long it took to shut off a 36-inch gate, was drawn by the faithful guardian, until normal conditions and pressure were recorded. That record places beyond dispute any and all claims as to time and duration of that break, with reference to damage suits, quantity of water possible to have been discharged, and other important items. Not the least part of the value of pressure records in this particular case, although an incidental one, was the high order of discipline and attention prevailing among the engineers in consequence of such a system at the pumping station, and which, no doubt, saved the city a pretty sum of money by reason of the prompt control of the large pumping engines suddenly relieved from pressure.

Another example of equal interest was that of a well-known water company, operating under a franchise, and under contract to furnish fire service. In the first two months of the use of the recording gauges, it was discovered that the engineer left his engine in the care of the fireman, while taking a nap; the fireman left his boiler in charge of the engineer while he took a nap, or went upon an errand. It was also learned that assistant engineers went home at night instead of attending to their duties, and depended upon their wives to wake them up about the time they thought they ought to get around. There used to be a variation in the water pressure at the pump of twenty pounds, which was finally reduced to five pounds, but when the gauge was applied to the main near the water office, two miles or more from the pumping station, it was discovered that at many times, when the vibration was not more than five pounds at the pumps, it varied from twenty to one hundred pounds at the office, demonstrating that restrictions and water ram existed in the mains somewhere near the office. Some patient investigation, assisted by moving the gauge from point to point, after a while pointed out how to remedy the difficulty, but also brought home the fact that a very material loss had been quietly submitted to by the water company for several years, simply because they were unaware of the existence of inadequate distribution.

At one time the president of the water company was absent from home, and received a telegram that there was a serious fire in the lower part of the city, and that there was no water pressure. Upon reaching home he found the city council up in arms against the water company. He detached a section of the recording gauge chart that had been produced during the time covered by the fire, took it to the Mayor and said :—"I wish you would exhibit that to your councilmen ; it shows the water pressure at the time of the fire. If you want to test the accuracy of that gauge here or elsewhere, you can do so at our expense, but do not condemn us until you find out where the fault was." An investigation developed the fact that the fire department, either through negligence or design, did not open the fire-plugs widely enough, and the fidelity of the water works officials was fully proven. The Mayor finally returned the card of record, with the statement that, in consultation with the legal authorities, and also with the council of the city, they had agreed that the water works company was not at fault, and that the threatened attack upon the company's franchise would not be made. It might be of interest to add, that the practice of the above water company, is to take off the charts at noon, when the names of the engineer and firemen on duty are

marked on them, with the location of any fire that has occurred. The chart itself shows the duration of the fire, or rather the time when the pressure was raised, and its continuance. These records are found useful, and are filed away.

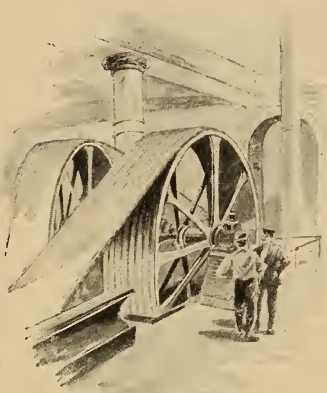
Referring to other uses of the recording gauge, it has been applied to the great American oil pipe lines, from the oil fields to the seaboard, where it is necessary to use heavy pressures, reaching as high as 1100 and 1500 pounds per square inch at the pumping stations. Bursts in the lines, with the attendant fires, were of frequent occurrence, but by the use and benefit of the pressure record, pointing out, as it did, abnormal conditions, sudden rises in pressure, caused by trouble with the pipes, and which would burst a pipe before any one noticed the rise for a few seconds in the already heavy pressure, were prevented. Since the introduction of the recording gauge, the troubles of abnormal pressures and breaks in the pipe lines have been entirely avoided. There are now nearly three hundred recording gauges in operation on the oil pipe lines, and their total cost sinks into insignificance compared with the losses they have prevented.

In refrigerating or ice-making machines, the record chart will enable the owner or operator to keep matters and results completely in hand and under control. He controls the plant continuously, because the gauges furnish correct records during every hour of the twenty-four. It becomes easy to perceive absolutely whether the plant has always been working under the conditions prescribed by the responsible head of the department or establishment,—that is, whether a stated suction or back-pressure previously determined upon, has been maintained, and whether the condensing pressure has been uniform. It can easily be seen whether water has been supplied in sufficient quantities to the condensers, and, if not, it will be shown where the inequalities took place, and to what extent. The gauges will also indicate if the machinery was stopped, and exactly at what hour of the day or night such stoppage occurred. They will tell if the machine was stopped accidentally or purposely, and it is also possible within certain limits to ascertain the cause of such stoppage. In fact, any unusual occurrence, as well as the regular running of the machine and plant, is correctly and faithfully traced upon paper slips, which furnish an extremely desirable record of reference. The advantage of keeping these records are so obvious and manifold, that their importance will suggest better methods of operation resulting from such practice ; and exactly as in the case of the firemen managing the boilers under his charge, the effect upon the men who regulate the expansion valves in connection with refrigerating machinery, can be plainly and instantly perceived, when once it becomes known that the records of results may be utilized in governing the pressure.

There are many other uses to which the recording gauge may be put, covering a wide range of the useful arts, involving the employment of various gases and fluids, embracing either pressure or vacuum as generally understood ; governing by co-incident factors, heat, cold, electricity, and motion.

THE DOWN-DRAUGHT FURNACE FOR STEAM BOILERS.*

By William H. Bryan.



PROBABLY no mechanical device has done as much toward the practical solution of the smoke problem in St. Louis as the down-draught furnace. Until this apparatus was developed there was a certain character of steam plants—or, rather, of steam service—to which it seemed that none of the existing forms of smoke-abating furnaces could be satisfactorily applied. In these plants—fortunately few in number—the demand for steam was such as to make it necessary at times to crowd the boilers far beyond their rated capacity. Or else the work was subject to frequent and extreme fluctuations, often greatly exceeding the rated capacity of the boilers. It may be said, of course, that this is abuse, rather than proper use, of a boiler plant, but, nevertheless, these conditions exist, and it is sometimes impossible either to modify the conditions or increase the boiler capacity.

The fact that there seemed no practicable or reasonable remedy for these cases retarded the growth of the smoke abatement movement in St. Louis for many years. It was thought unwise to pass and attempt to enforce smoke-abatement ordinances when it seemed impossible for some of the plants to stop the smoke, under reasonable conditions. The demonstration of the fact that the down-draught furnace made a good smoke record possible, even with overworked boilers doing variable work, and with a marked economy in fuel, may be said to have marked an epoch in smoke abatement. Our experience in St. Louis leads us to believe that smoke from boiler furnaces can now be abated by practical means, without hardship, no matter what the type of boiler, the character of the work required of the plant, or the kind of fuel used.

I speak thus highly of the down-draught form of furnace with no intention of denying the merits—for they are many—of other smoke-abating devices. Many of these do excellent work under most of the conditions occurring in practice. In my opinion, however, no single furnace now on the market can be adapted to all the conditions met with in everyday boiler service. Each type has a place, a field of usefulness, within which limits its success is sure. Unfortunately, however, the average furnace man seems unable to realize this truth, but offers his device as a remedy for all sorts of cases and conditions. It is not surprising, therefore, that he sometimes meets with failure.

Where the work required of a boiler plant does not greatly exceed its rated capacity, and is reasonably uniform, there are many good smoke-abating furnaces which may be used, some of which will make an appreciable saving in fuel. If boiler plants were properly designed and managed, and if we did not have sometimes to overwork them, and to subject them to widely varying loads, the smoke-abatement problem would be greatly simplified.

Fortunately for the steam-using

* From a paper read before the American Society of Mechanical Engineers, June, 1895.

public, several different forms of down-draught furnaces are offered for sale, by various builders, and under different patents I have had no opportunity of looking up the number and value of these patents, but it would seem that they refer to important details of construction and arrangement, rather than to general or essential principles. It is not necessary to consider here whether or not the manufacturers are justified in charging royalties. Their experience in the design and adaptation of the furnace to varying conditions—and the further fact that, as a rule, they will guarantee results — would certainly appear to entitle them to a fair margin of profit, at least.

Although the principles are old, I have been unable to find any record of this type of furnace coming into regular use previous to 1888. It seems that the cost of the apparatus, the necessity for water grates, and their frequent burning out, due to defective construction and bad feed-water, prevented its general adoption.

The form of down-draught furnace which has come into most general use, and which may justly be said to have contributed more than any other to the present state of the art, is that invented by Mr. M. C. Hawley, of St. Louis, and which bears his name. Mr. Hawley's experiments began as far back as 1873, and met with varying degrees of success. He was able to show an economy of fuel, and, with proper handling, an almost total abatement of the smoke, even with the low-grade soft coals common in the Mississippi valley. In 1882 Mr. Hawley interested Capt. C. W. Rogers, then general manager of the St. Louis and San Francisco railway, who, after consultation with his master mechanic, decided to build an experimental furnace in the fire-box of a switch engine. The result was so satisfactory that the furnace was soon applied to another locomotive boiler in stationary service. It was then applied to a locomotive in regular service. It was necessary to greatly cut down the grate area, but in spite of this the engine did good service, being practically smokeless, and throwing no sparks, even with a straight stack and no netting, until destroyed by a round-house fire. The furnace was also applied to a number of the boilers of the St. Louis and San Francisco Railway company, in stationary practice, in their shops and other buildings, where they are still running satisfactorily.

In 1888 a contract was made to place the Hawley furnace under an ordinary stationary boiler in the new factory of the Hamilton & Brown Shoe Company, St. Louis, under a very stringent guarantee. The boiler was 60 inches diameter, 20 feet long, with eighteen 6-inch flues A similar boiler was set with the ordinary furnace, in the same room. The results in smoke abatement, fuel economy and capacity were so satisfactory as to lead to the application of the Hawley furnace to the other boiler very shortly afterwards. This case marked the beginning of the introduction of this type of furnace into general stationary practice.

A brief description of the characteristic features of the Hawley setting will be of interest. In the earliest forms it consisted of a single row of water grates, these being necessary on account of the high temperatures developed. These water grates were made of 2-inch pipe, placed level and connected with the circulation system of the boiler by water boxes, or headers, and connecting pipes. The supply pipe leading to the front headers was usually taken from near the bottom of the front end of the shell, and the discharge was delivered near the water line. The rear end of the fireplace, above the grates, was closed off tightly, by means of a hanging water leg, riveted to the shell of the boiler, in which suitable openings had been cut. In order to insure circulation in the tubes and prevent their burning off, it was found necessary to have the rear end of each tube project far enough into the water leg to permit attaching an elbow, into which was screwed a riser, reaching up into the main body of the water in the boiler. Further experiments showed that it was usually desirable to put in two rows of

water grates, and to stagger them. Even then, however, a considerable amount of unburned fuel fell through the grates, and was hauled out with the ashes, unconsumed. This caused a loss of efficiency when the boilers were crowded, and led to the adoption of the lower grate, which is of the ordinary pattern. This form of the furnace is shown in Fig. 1.

It was at the Hamilton and Brown Shoe Works, above referred to, that the necessity for the lower grate became evident, and where it was first applied by Mr. Hawley. It is now an accepted feature of all forms of the Hawley furnace, and to it, in my opinion, are largely due the excellent results secured in capacity, efficiency and smokelessness.

In the earlier forms of the furnace the water grates were level. It was soon found that, by placing them on an incline, rising to the rear, the circulation was much improved, and the probability of burning off tubes greatly reduced. This plan was then regularly adopted, and the pitch gradually increased until the standard is now 2½ to 3 inches per foot of grate length.

It was soon found, also, that the riser pipes in the rear water box were a source of trouble. Sometimes they became disconnected from the elbows, and when new grates were put in it was difficult to attach the elbows and risers, on account of interference with the other risers and with stay-bolts. When the risers were not connected, the grates burned off in a short time. This proved a serious difficulty, requiring, in a number of plants, the almost constant presence of boiler makers. Part of the boiler plant was therefore out of service a large portion of the time, and repair bills were large. Experiments were then made with other forms of construction, and a water box, or header, was finally adopted for the rear end, similar to that used for the front end of the grates, the space intervening between it and the shell of the boiler being built up solidly by a 9-inch firebrick wall. Connections were made from each end of the rear water box to the boiler shell, some distance back from the front of the boiler, and just below the water line. This expedient proved satisfactory, greatly reducing the number of tubes burning off.

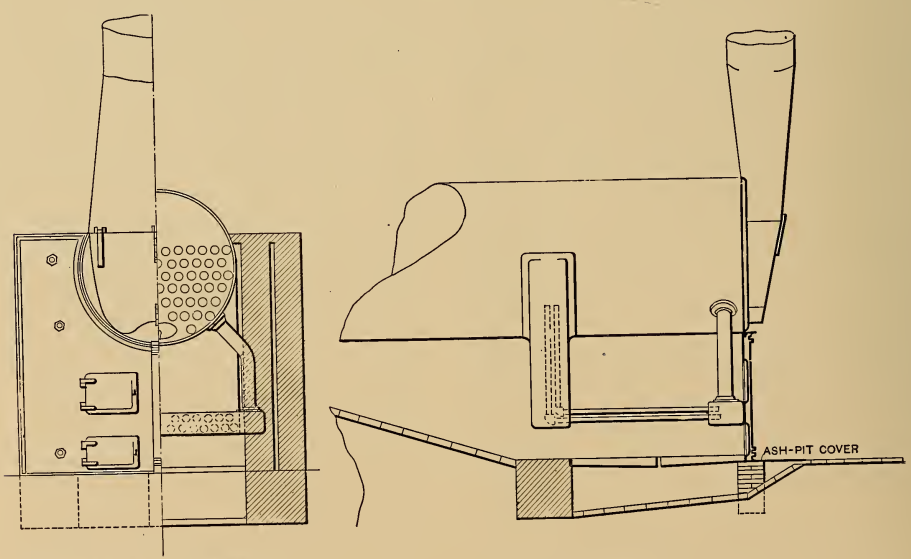


FIG. 1. THE EARLY HAWLEY FURNACE.

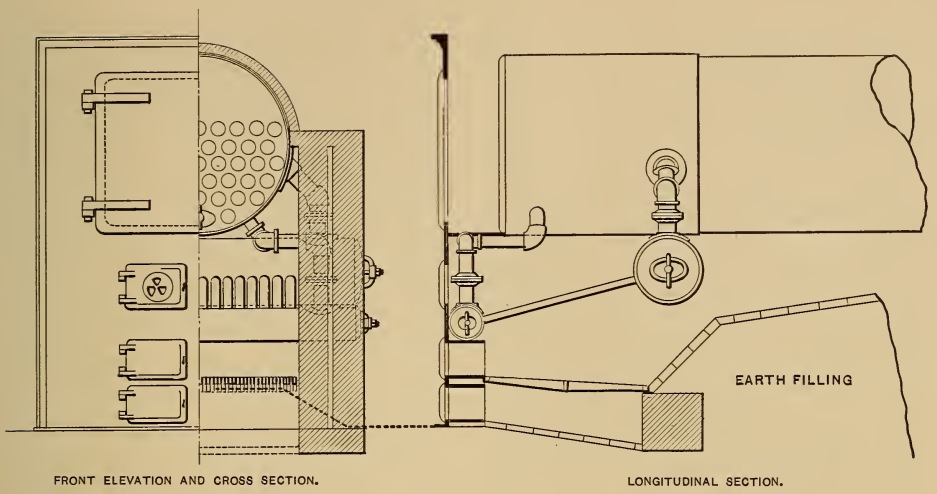


FIG. 2. THE LATEST FORM OF HAWLEY FURNACE.

This rear drum is now made in two forms. That adopted by the St. Louis manufacturers is simply a riveted drum 20 inches in diameter. This large radius permits the water grates to be screwed in, without the necessity of flattening the sides of the tube, as is customary with the form adopted by the Chicago manufacturers, whose rear drums are 10 inches in diameter. In the St. Louis form the drum is large enough to permit a man to enter it. By placing a light through a hand-hole into the front drum—which is usually 8 or 10 inches diameter—it is possible to look through every tube, and thus ascertain its exact condition. The large drum, however, offers a favourable place for the accumulation of sediment, which may cause it to burn, on account of the high temperatures to which it is exposed. No such accident, however, has occurred, so far as I can learn. Fig. 2 shows the St. Louis form of construction. It shows but a single row of water grates, this form still being frequently used, as being easier handled.

This figure also shows the present method of building the boiler fronts. In the early form, shown in Fig. 1, the ashpit was wholly below the floor line, and was extended out in front of the boiler front, that portion of it being covered with sheet-iron plates, which were removed when cleaning the ashpit. This arrangement proving unsatisfactory, it was replaced by the three-door front shown in Fig. 2. This plan raised the average level of the upper grates to a point some 18 inches above that of the ordinary furnace, making it necessary for the fireman to lift the coal that much higher, and making the firing considerably more labourious. It has now become customary to raise the floor a little at a point some three feet away from the front (see heavy dotted line in Fig. 2), thus permitting the fireman to stand at the usual level with reference to height of grate. It is desirable also to have the ashpit slope to the rear, to facilitate cleaning.

As will be clearly seen from the drawings, the operation of the down-draught furnace is directly opposite to that of the ordinary setting. Very little air is admitted below the water grates; the entire supply of coal, and practically all the air, enter above. The fire burns downward instead of upward, there being "no thoroughfare" except downward through the grates. The gaseous products of combustion, together with the finely divided carbon particles which form the visible smoke, are forced through the incandescent mass of coal and are highly heated, after which they meet the equally hot flame from the

lower grates, on which there is burning what is practically a coke fire. The combined water of the volatile matter in the coal, as well as its moisture, are decomposed into hydrogen and carbonic oxide gases. These combine with air supplied below the grate, or drawn downward through it, and burn, thus adding to the efficiency of the furnace instead of impeding it. The separated carbon meanwhile is transformed into carbonic acid gas, which is invisible. The result is almost complete combustion. Such little additional air as is needed is furnished through the registers of the doors between the two grates, or through those of the ash-pit, the doors of which are sometimes left partly open also.

In practice it is found that, as an average, the upper grates do probably 90 per cent. of the work. When the boilers are not crowded little or no fuel is burned on the lower grates. When there is a demand for an increased amount of steam the fireman runs his slice bar along or between the upper grates, causing a considerable amount of half-burned coal to drop through to the lower grates, where its combustion is completed.

It will be seen that the water grates and headers add somewhat to the heating surface, and thus increase the capacity of the boiler. It has been found, however, that this reversing of the path of the gases, and requiring them to traverse the tortuous passages, makes necessary a somewhat increased chimney capacity, if it is desired that the boilers be capable of doing as much work as with the ordinary setting. If the demand for steam never greatly exceeds the rated capacity of the boiler, the ordinary chimney will answer, it simply being necessary to carry thinner fires. The best results, however, in efficiency and smokelessness, as well as in capacity, are secured by having a chimney of ample height; a statement, however, which is equally true with regard to ordinary settings, which rarely have enough chimney.

In order to make a fair and definite comparison of the Hawley down-draught setting with the ordinary furnace, the Smoke Commission of the city of St. Louis, of which the writer is a member, made a competitive test at the plant of the William J. Lemp Brewing Company, on July 11, 1893. The boilers were identical in every respect except as regards their furnaces, and that the chimney for the down-draughts was 143 feet high, and for the common battery 100 feet high, above grate level. In both cases the boilers were run at more than double their normal rating, and the efficiency of the Hawley was over 21 per cent. higher than that of the common furnace.

The smoke record showed a reduction in the smoke of nearly 96 per cent., even under these extraordinarily severe conditions. A chart made by the writer from the chimney of a Heine boiler, set with the Hawley furnace, at a time when the boiler was being run at 25 per cent. above its rating, showed the remarkably low figure of only ⅔ of 1 per cent. of smoke—in fact, there was absolutely no smoke except while the fires were being cleaned.

It will be seen in Figs. 1 and 2 that in the standard form of construction the fireplace is immediately under the front end of the boiler. This usually cuts off from 50 to 60 square feet of valuable shell heating surface, and, furthermore, must interfere largely with the circulation of the water in the boiler. In a few instances external fireplaces have been built, but their somewhat greater cost, the increased space occupied, the necessity for a special form of front, and the difficulty found in supporting the fire-brick arches over the water grates, have prevented the general adoption of this plan. In my opinion, however, it possesses important advantages in capacity and efficiency, and should be followed wherever sufficient space is available.

With the present form of water-drums and tubes there is but little danger of the tubes burning out unless the feed-water is bad. This is a point that must be carefully looked into when it is proposed to use the down-draught furnace. It is a matter, however, that

should always have attention, whatever the type of boiler or setting; and as there are now so many good systems of water purification there is little excuse for permitting heating surfaces to become foul with scale. When the tubes burn out, they do so without causing damage to the surroundings. Sometimes only the threads are stripped, and at other times the tube splits, resulting in a large, but not serious, leak of water. In such cases the boilers are generally run in their regular service until the usual time of shutting down, and cases are on record where the boilers have been run until Saturday night —almost a full week. It is desirable, however, that at least one side of the boiler be accessible, in order to afford access to both drums, particularly with bad feed-water. This necessitates a passage-way between each pair of boilers.

A few cases of grate renewals have been due to careless or ignorant handling of the slice-bar by the fireman, bringing a severe cross-bending strain on the tubes. This, of course, must be carefully guarded against. There being considerable special ironwork connected with the Hawley setting, this type of furnace is necessarily more expensive in the first cost than some others. Measured in results, however, the advantages would, in most cases, appear to warrant a considerably greater investment than is ever required.

The conditions under which it would appear unwise to use the Hawley down-draught furnace for smoke abatement would seem to be:

First.—Where the feed-water is quite impure, and cannot be readily improved.

Second.—Where the feed-water is bad, and the boiler is not accessible from the side.

Third.—Where the draught is poor, and the boilers are hard worked. Usually, however, the height of chimney can be increased.

Fourth.—Where there is but a single boiler. The possibility of an occasional tube renewal might cause the interruption of the service for several days. This danger would be very remote with reasonably pure feed-water.

Fifth.—Where the plant is of such a size or character as not to warrant the investment.

Evaporative tests made by myself and others indicate that the Hawley furnace adds to the efficiency of improved water-tube forms of boilers, although the percentage of increase is not so great as with the ordinary boilers. The design of the furnace is such as to make it readily applicable to any form of boiler.

I recently prepared a series of instructions to firemen for a large plant operating the down-draught furnaces. These are appended hereto. It will be seen that the requirements are not at all difficult of comprehension and execution.

In some cases the use of this furnace has been found to add to the labour cost. This was due in a few cases to the increased height to which the coal had to be lifted, and sometimes to the debilitating effect of the radiant heat pouring out through the open fire-doors into the face of the fireman. Raising the floor level has remedied the former trouble, and the latter has been largely reduced by an improved form of door, which can be so placed as to keep the heat off the fireman, while still admitting an ample air supply. In other cases the draught was insufficient, and large demands for steam have necessitated increased labour. In still other cases, the firemen have not thoroughly understood the best method of handling the fires, and have not directed their efforts to the best advantage. With the latest form of construction, proper draught, intelligent and careful handling of the fires, there would appear to be no reason why the amount of labour should be increased. On the contrary, it ought to be decreased, as there is less coal to be handled.

Not the least of the many advantages afforded by the down-draught type of boiler furnace is the fact that the heating surfaces are exposed to practically constant temperatures. There is no

alternate heating and cooling, as is the case with the common setting, when the doors are opened to admit fresh charges of fuel. That this type of boiler setting is destined to widespread use is demonstrated by that fact that three companies alone have within the

lessness and efficiency were fully realized. I had expected some loss in capacity, due to the necessarily limited percentage of air-space through the firebrick grates, but in this I was agreeably disappointed.

The difficulty with this setting thus

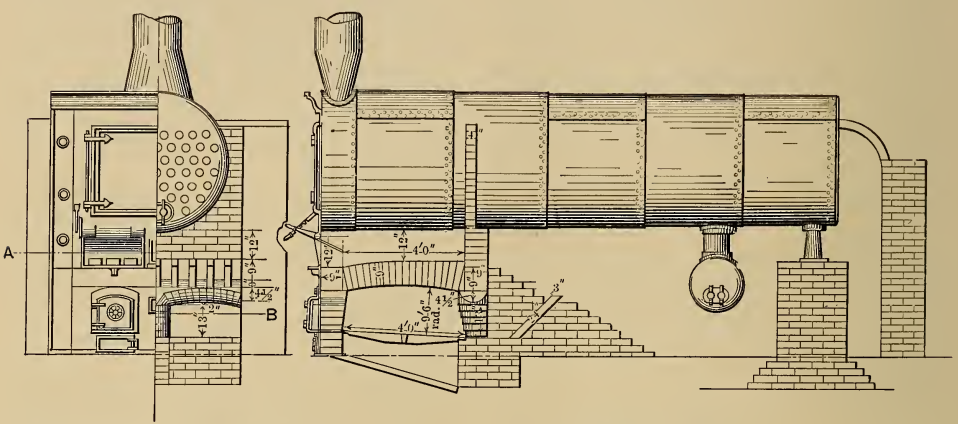


FIG. 3. THE THOMAS FURNACE.

last five years applied it to 1600 boilers, aggregating 240,000 horse-power.

While the Hawley type of down-draught furnace is perhaps the best known, others are coming into use, which promise well, although none have, as yet, met with very wide adoption. One of these, invented by Mr. Jos. M. Thomas, of St. Louis, is shown in Figs. 3 and 4. In essential characteristics it resembles the Hawley, the principal point of difference being the substitution of a series of firebrick arches in place of the water grate.

It possesses two important advantages : first, the absence of any connection with the pressure system of the boiler, thus avoiding trouble from that source ; and, second, the brick arches act as reservoirs of heat, and do not cool the fires as the water grates do. It would be reasonable, therefore, to expect higher temperatures, and increased efficiency and smokelessness. Appended hereto are found the results of two tests made by the writer on boilers set with and without the Thomas furnace. My expectations as to smoke-

far has been the short life of the grates, varying from thirty days to six months, depending entirely upon the character of the service, and the care with which the firing is done. Where the boilers are crowded, or where the firemen are careless, the arches last but a short time. If their durability could be increased to an average of, say, four months—which ought to be possible with careful handling, if the boilers are not unduly crowded—the small expense and trouble connected with their renewal would be fully warranted by the improved results. Experiments are now in progress with a view of securing a more highly refractory material out of which to make the grates, and until this is found, no extended effort will be made to push the introduction of the furnace.

Another form of down-draught furnace has been developed by Mr. J. A. Baldwin, of Benton Harbor, Mich. It is similar in many respects to the Hawley, the principal difference being that, instead of admitting the air through open doors above the water tubes, it

enters through ducts in the masonry side walls, thus being preheated to some extent. Part of this air is discharged above the water grates, and part below them. The lower grates, instead of being ordinary bars, consist of perforated wrought-iron plates. The preheating of the air should be an advantage, if it is not accomplished at the expense of some other desirable feature, such as smokelessness, capacity, or efficiency. Only a few of these furnaces have been built, and I have had no opportunity of examining them myself, but I am told that they are doing good work. No accurate evaporative tests have been made.

Another form is that invented by Mr. W. S. Plummer, of St. Louis. Mr. Plummer has all his grate surface on one level, and divides it lengthwise into three parts. The two outer parts are of the ordinary pattern of up-draught grates, while the central portion consists of water tubes connected with the circulation system of the boiler. A water grates. The plan is working satisfactorily on a small scale in St. Louis, and is now being applied to a large boiler plant, where its operation will be watched with interest. The difficulty would seem to be the necessity for great width of grate surface, it being necessary to get the entire amount of surface in one level, while, in the Hawley furnace, it is divided over two different parallel planes. An increase can, of course, be had by lengthening the grates, but this is not always desirable.

A somewhat similar form is that invented by Mr. E. M. Bosley, of St. Louis, and applied in several cases in connection with his "incandescent" internally fired boilers. He divides his firebox into two parts with the dividing line at right angles to the centre of the boiler. The front half consists of an ordinary up-draught grate. In the rear of this is a 10-inch front water drum or header, extending clear across the furnace, and connected by means of 2-inch

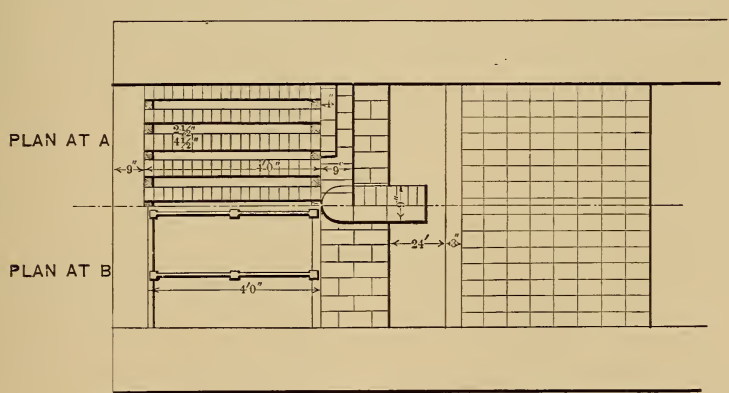


FIG. 4. PLAN OF THE THOMAS FURNACE.

solid brick wall blocks off the rear of the fireplace, and extends down to the bottom of the ashpit, except immediately under the rear end of the water tubes. There are two partition walls in the ashpit, running lengthwise, which separate the up-draught from the down-draught portion of the furnace. The firing is done just as in the ordinary furnace, but the only escape for the gases is downward through the central water grates to a similar drum in the rear. An ashpit of the usual form is built under the front grate, and a closing-off wall above the rear drum. The fire is burned on the front grate in the usual manner, a bed of fire being also carried on the water grates. The path of the gases is up through the front grate in the usual manner, and down through the water grates in the rear. A lower ashpit permits access from the

front to the space underneath the water grates.

Both the Plummer and Bosley forms of down-draught furnaces appear to utilize the heating surface of the shell immediately overhead to better advantage than the Hawley, but, on the other hand, neither of them have the second grate located where it will catch and consume the droppings from the water grates. So far as I know, no exhaustive investigations or tests of either of these types of setting have been made.

There are other types of down-draught furnace, notably that of Post & Sawyer of Boston, which I believe has been applied only in connection with their internally fired "Complete Combustion" boiler, and which does not use a lower grate. The other forms are, in general, modifications of those described here, being few in number and relatively unimportant.

The system in its best shape is not perfect. Much has been done during the last few years in improving details so as to increase the efficiency, durability, and reliability of the apparatus, but there is room for further improvements. Even in its present condition, however, it is well worthy of the careful study of progressive engineers everywhere.

INSTRUCTIONS FOR THE OPERATION AND CARE OF THE HAWLEY DOWN-DRAUGHT FURNACE, TO SECURE EFFICIENCY AND PREVENT SMOKE WITH ILLINOIS COALS.

PREPARED BY WILLIAM H. BRYAN, CONSULTING ENGINEER, ST. LOUIS.

Fire frequently and in small quantities. Break up the lumps to fist size. Fire on the upper grates only, carrying a bed of uniform thickness over the entire grate surface. Avoid thin or bare spots.

The proper thickness of fire-bed depends upon the intensity of the draught and size of the coal. Lump coal and good draught require a thick fire, say 8 to 10 inches, while fine coal and poor draught may render it necessary to reduce the thickness as low as 4 inches. Don't let the elevation of the grates at the rear deceive you, but be sure the thickness of the fuel-bed is the same there as at the front.

When slicing, be careful that no green coal falls through to the lower grates. Do not let green coal get to the under side of the upper fire next to the water grates. When slicing, push the bar between or along the water grates, and draw it back again without disturbing the fire. Lift the slice-bar just enough to break the cake bed. Use the slice-bar as little as possible. Be very careful not to strain the tubes with the slice-bar.

See that the bed of coal on the upper grates do not get either too thick or too thin. The former will reduce the capacity, and the latter cause smoke.

Do not close the upper doors while fresh coal is on the fires.

Do not reduce the draught by closing the dampers, shutting the fire doors, or otherwise, except when absolutely necessary.

Keep the lower grates well covered, but do not let the bed get too thick, nor permit clinker to accumulate.

Keep the doors between the upper and lower grates closed, except when cleaning lower grates, say two or three times a day.

Admit a small amount of air under the lower grates, except when they are bare immediately after cleaning.

When cleaning the upper grates see that none of the water tubes are uncovered or exposed. The quantity and location of clinkers can usually be determined by running the slice-bar through the fire. They can then be loosened and hooked out without seriously disturbing the fire-bed. It is better to watch for clinkers closely, and hook them out as fast as they are formed, rather than to attempt a general cleaning of the entire fire-bed at one time.

Do not clean the lower grates when there is much green coal on the upper grates. Immediately after cleaning slice the upper grates carefully, so as to get a covering of live coals for the lower grates.

The ashpit should be cleaned as often as is necessary to keep it from filling

up and obstructing the admission of air to the lower grates. Never clean the ashpit while the lower grates are bare or thinly covered.

Clean as quickly as possible, so as to avoid cooling the fires.

When cleaning the boilers, see that the circulating pipes, and front and rear drums, to which the water grates are connected, are thoroughly washed out under pressure. Those parts which can be examined should be looked into at frequent intervals, and those which can be cleaned by mechanical means should have frequent attention. Where accessible, the water grates should be washed out by inserting a hose into each one.

A FIRE BRIGADE AT CONSTANTINOPLE.

TURKISH FIRE ENGINES.

By J. Arthur Grey.

HOW often do we hear people talk of the "good old times" without their having the least notion of what they are talking about, or of the irony which the reference conveys. If they would dispel that delusion they should take Macaulay's History and read that famous chapter in which he gives such a graphic comparison between the "good old times" and the

THE BRIDGE OF GALATA, CONSTANTINOPLE

times we live in now. If that does not convince them of their mistake, let them pay a visit to Constantinople, and there they will find a state of things that resembles, in many respects, the good old times for which they sigh.

There they will find that history seems pushed back about a hundred years, certain old customs still prevailing that were quite old-fashioned in most parts of Europe more than a century ago. The Turks are thoroughly conservative. They adhere tenaciously to antiquated and patriarchal notions. It is not the province of an article in an engineering magazine to take notice of customs, social, commercial or political, of any country, however remote, and Turkey is far from being a *terra incognita* to travelers, American or English. But there exists in that semi-oriental region at least one institution that has some relation to mechanical matters, and that is the apparatus for extinguishing fires.

A glance at the illustration on page 581 will show at once the species of fire engine and the constitution of the fire brigade of which Constantinople boasts. The engine consists simply of a hand pump, supported on two long poles, and carried on the shoulders of four of the firemen. The photographer has evidently caught the brigade returning from an expedition, and, by tipping the Bachi, has got the party to pose for a moment.

When these fellows are proceeding to a fire they make a great show of haste. They run at a brisk trot, and keep shouting and yelling all the way, pushing rudely aside all wayfarers who are unlucky enough to get in their line of march. But in truth, Turks are seldom in a hurry. It may be that their speed, on setting out, is stimulated more by the expectation of being able to levy "backsheesh," if they are early on the scene, than by any ardent desire to quench fire. The clothing they wear is white, and their lower limbs and feet are bare ; consequently their progress is noiseless, but for the yells they emit as they push along.

There is a high tower in Stamboul and another on the other side of the Golden Horn at Galata, both of which display flags on the alarm of fire. The flags are supposed to indicate the locality of the fire, but as several localities are sometimes enlivened by fires about the same time, these indications cannot always be very explicit. If fires break out during the night, the Bekjies (night watchmen) take up the cry, and bawl out with discordant intonation where the fire is supposed to be.

When that formidable company of firemen with the hand pump arrive on the scene of conflagration, the Bachi first of all calls at the contiguous houses, as yet untouched by fire, and endeavours to extort backsheesh for the exertions his men are about to make to save property. And woe betide those who admit these rascals ! For the furniture is dragged out into the street, and if the household goods are not plundered there, they are probably destroyed beyond recovery. The writer has been told that householders generally prefer to bolt their iron doors and shut their iron shutters rather than give access to those plundering ruffians. Their extinguishing apparatus is generally of little avail.

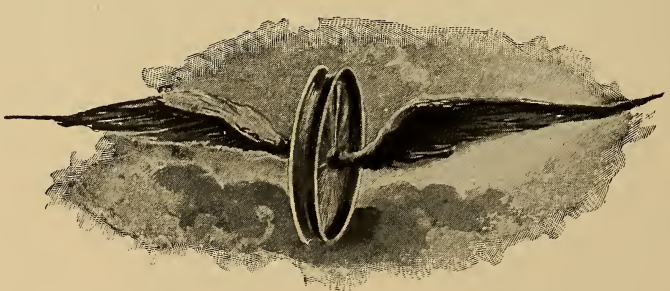
There are water pipes throughout the principal streets of Pera, but fire plugs are not numerous, and if the fire should be in an outlying district, where water can only be obtained from wells, it is easy to understand that any efforts these "pompiers" may be able to make are of very little account. At the time of the great fire that destroyed a large part of Constantinople about 30 years ago, there was no system of water supply, and wooden houses were more numerous than now. There have been no such serious devastations by fire since. But there are now a good many stone and brick buildings interspersed among the wooden houses, and as these are all provided with iron doors and shutters, they help to stem the progress of the devouring element.

It is said that there are now in Constantinople one or two steam fire engines that were purchased in Eng-

land. But although the writer has lived there more than seven months, he has never yet seen anything there of the fire engine species of a more pretentious character than the brigade here depicted. The explanation is that these steam fire engines are taken out only to large conflagrations, and because only a few are accessible to them. It is true that neither in Stamboul nor in Pera are there many streets that would permit of the passage of a cumbrous steam fire engine. There is in Pera only one road—that is, the tramway road,—which runs from the harbour at Galata up to the high parts of the city, and joins the Grand Rue near the English Embassy. Below that, and through the most densely populated parts, there are only narrow, steep and crowded thoroughfares, paved in parts only in the roughest manner, and along which no kind of carriage traffic is practicable. These circumstances may account in some measure for the miserable turn-out of fire extinguishing machinery. It would surely be in the interest of fire insurance companies if a few light steam fire engines were established at some high stations in the Turkish capital.

The photograph of the bridge of Galata, reproduced on page 582, is taken from the Stamboul side, and on the other side of the Golden Horn are Galata and Pera, where most of the Greeks and other Europeans reside. On the highest part of Galata stands the fire tower, whence the signals of fire are given. A little below it stands the handsome new building of the Imperial Ottoman Bank.

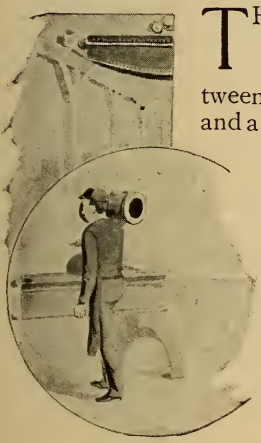
This bridge of Galata is the principal means of communication between the two great divisions of Constantinople—Stamboul and Pera—and is a busy scene from early morning till late at night. It is estimated that an average of 30,000 persons cross the Golden Horn by this bridge every day, and all, except Turkish women who are readily known by their apparel, have to pay a pontage of ten paras (about a half penny, English). Carriages and cabs pay ten piastres. The collectors are three or four Turks, clothed in white, who stand at each end of the bridge. It is quite an interesting sight to see the crowd of red fez's coming and going. The bridge is carried on floating pontoons, with a portion in the middle that can be withdrawn. It is opened only in the middle of the night to allow vessels to pass out or in. The surface of the roadway is made up of transverse logs of rough timber, without any attempt at levelling, and carriages jolt so violently as to make their occupants feel in danger of being thrown out. Some of the pontoons carry shops and coffee houses, and there are landing stages for the steamers on both sides.



A PIECE-RATE SYSTEM.*

A Step Toward a Partial Solution of the Labour Problem. —

By Fred. W. Taylor.



THE ordinary piece-work system involves a permanent antagonism between employers and men, and a certainty of punishment for each workman who reaches a high rate of efficiency. The demoralizing effect of this system is most serious. Under it, even the best workmen are forced continually to act the part of hypocrites, to hold their own in the struggle against the encroachments of their employers. The system introduced by the writer, however, is directly the opposite, both in theory and its results. It makes each workman's interests the same as that of his employer, pays a premium for high efficiency, and soon convinces each man that it is for his permanent advantage to turn out each day the best quality and maximum quantity of work.

The writer has endeavoured in the following pages to describe the system of management introduced by him in the works of the Midvale Steel Company, of Philadelphia, U. S. A., which has been employed by them during the past ten years with the most satisfactory results.

The system consists of three principal elements :

(1) An elementary rate-fixing department.

(2) The differential rate system of piece-work.

(3) What he believes to be the best method of managing men who work by the day.

Elementary rate-fixing differs from other methods of making piece-work prices in that a careful study is made of the time required to do each of the many elementary operations into which the manufacturing of an establishment may be analyzed or divided. These elementary operations are then classified, recorded and indexed, and when a piece-work price is wanted for work, the job is first divided into its elementary operations, the time required to do each elementary operation is found from the records, and the total time for the job is summed up from these data. While this method seems complicated at the first glance, it is, in fact, far simpler and more effective than the old method of recording the time required to do whole jobs of work, and then, after looking over the records of similar jobs, guessing at the time required for any new piece of work.

The differential rate system of piece-work consists briefly in offering two different rates for the same job ; a high price per piece, in case the work is finished in the shortest possible time and in perfect condition, and a low price, if it takes a longer time to do the job, or if there are any imperfections in the work. (The high rate should be such that the workman can earn more per day than is usually paid in similar establishments.) This is directly the opposite of the ordinary plan of piece-work, in which the wages of the workmen are reduced when they increase their productivity.

The system by which the writer proposes managing the men who are on day-work consists in paying men and

* From a paper presented at the Detroit meeting (June, 1895) of the American Society of Mechanical Engineers.

not positions. Each man's wages, as far as possible, are fixed according to the skill and energy with which he performs his work, and not according to the position which he fills. Every endeavour is made to stimulate each man's personal ambition. This involves keeping systematic and careful records of the performance of each man, as to his punctuality, attendance, integrity, rapidity, skill, and accuracy, and a readjustment from time to time of the wages paid him, in accordance with this record.

The advantages of this system of management are :

First. That the manufactures are produced cheaper under it, while at the same time the workmen earn higher wages than are usually paid.

Second. Since the rate-fixing is done from accurate knowledge instead of more or less by guess-work, the motive for holding back on work, or "soldiering," and endeavouring to deceive the employers as to the time required to do work, is entirely removed, and with it the greatest cause for hard feelings and war between the management and the men.

Third. Since the basis from which piece-work, as well as day-rates, are fixed is that of exact observation, instead of being founded upon accident or deception, as is too frequently the case under ordinary systems, the men are treated with greater uniformity and justice, and respond by doing more and better work.

Fourth. It is for the common interest of both the management and the men to coöperate in every way, so as to turn out each day the maximum quantity and best quality of work.

Fifth. The system is rapid, while other systems are slow, in attaining the maximum productivity of each machine and man ; and when this maximum is once reached, it is automatically maintained by the differential rate.

Sixth. It automatically selects and attracts the best men for each class of work, and it develops many first-class men who would otherwise remain slow or inaccurate, while at the same time it discourages and sifts out men who are incurably lazy or inferior.

Finally. One of the chief advantages derived from the above effects of the system is, that it promotes a most friendly feeling between the men and employers, and so renders labour unions and strikes unnecessary.

There has never been a strike under the differential rate system of piece-work, although it has been in operation for the past ten years in the steel business, which has been during this period more subject to strikes and labour troubles than almost any other industry. In describing the above system of management, the writer has been obliged to refer to other piece-work methods, and to indicate briefly what he believes to be their shortcomings.

1. Capital demands fully twice the return for money placed in manufacturing enterprises that it does for real estate or transportation ventures ; and this probably represents the difference in the risk between these classes of investments.

2. Among the risks of a manufacturing business, by far the greatest is that of bad management ; and of the three managing departments, the commercial, the financiering, and the productive, the latter, in most cases, receives the least attention from those that have invested their money in the business, and contains the greatest elements of risk. This risk arises not so much from the evident mismanagement, which plainly discloses itself through occasional strikes and similar troubles, as from the daily more insidious and fatal failure on the part of the superintendents to secure anything even approaching the maximum work from their men and machines.

3. It is not unusual for the manager of a manufacturing business to go most minutely into every detail of the buying and selling and financiering, and arrange every element of these branches in the most systematic manner, and according to principles that have been carefully planned to insure the business against almost any contingency which may arise, while the manufacturing is turned

over to a superintendent or foreman, with little or no restrictions as to the principles and methods which he is to pursue, either in the management of his men or the care of the company's plant.

4. Such managers belong distinctly to the old school of manufacturers, and among them are to be found, in spite of their lack of system, many of the best and most successful men. They believe in men, not in methods, in the management of their shops; and what they would call system in the office and sales departments, would be called red tape by them in the factory. Through their keen insight and knowledge of character they are able to select and train good superintendents, who in turn secure good workmen; and frequently the business prospers under this system (or rather, lack of system) for a term of years.

5. The modern manufacturer, however, seeks not only to secure the best superintendents and workmen, but to surround each department of his manufacture with the most carefully woven net-work of system and method, which should render the business, for a considerable period, at least, independent of the loss of any one man, and frequently of any combination of men.

6. It is the lack of this system and method which, in the judgment of the writer, constitutes the greatest risk in manufacturing, placing, as it frequently does, the success of the business at the hazard of the health of whims of a few employees.

7. Even after fully realizing the importance of adopting the best possible system and methods of management for securing a proper return from employees and as an insurance against strikes and the carelessness and laziness of men, there are difficulties in the problem of selecting methods of management which shall be adequate to the purpose, and yet be free from red tape, and inexpensive.

8. The literature on the subject is meagre, especially that which comes from men of practical experience and observation, and the problem is usually solved, after but little investigation, by the adoption of the system with which the managers are most familiar, or by taking a system which has worked well in similar lines of manufacture.

9. Among the methods of management in common use there is certainly a great choice, and before describing the "differential rate" system, it is desirable to briefly consider the more important of the other methods.

10. The simplest of all systems is the "day work" plan, in which the employees are divided into certain classes, and a standard rate of wages is paid to each class of men, the labourers all receiving one rate of pay, the machinists all another rate, the engineers all another, etc. The men are paid according to the position which they fill, and not according to their individual character, energy, skill, and reliability.

11. The effect of this system is distinctly demoralizing and levelling. Even the ambitious men soon conclude that since there is no profit to them in working hard, the best thing for them to do is to work just as little as they can and still keep their position. Under these conditions the invariable tendency is to drag them all down even below the level of the medium.

12. The proper and legitimate answer to this herding of men together into classes, regardless of personal character and performance, is the formation of the labour union, and the strike, either to increase the rate of pay and improve conditions of employment, or to resist the lowering of wages and other encroachments on the part of employers.

13. The necessity for the labour union, however, disappears when men are paid, and not positions; that is, when the employers take pains to study the character and performance of each of their employees and pay them accordingly, when accurate records are kept of each man's attendance, punctuality, the amount and quality of work done by him, and his attitude towards his employers and fellow-workmen.

As soon as the men recognize that they have free scope for the exercise of their proper ambition, that, as they work harder and better, their wages are

from time to time increased, and that they are given a better class of work to do—when they recognize this, the best of them have no use for the labour union.

14. Every manufacturer must from necessity employ a certain amount of day labour which cannot come under the piece-work system ; and yet how few employers are willing to go to the trouble and expense of the slight organization necessary to handle their men in this way? How few of them realize that, by the employment of an extra clerk and foreman, and a simple system of labour returns, to record the performance and readjust the wages of their men, so as to stimulate their personal ambition, the output of a gang of twenty or thirty men can be readily doubled in many cases, and at a comparatively slight increase of wages per capita !

15. The clerk in the factory is the particular horror of the old-style manufacturer. He realizes the expense each time that he looks at him, and fails to see any adequate return ; yet by the plan here described the clerk becomes one of the most valuable agents of the company.

16. If the plan of grading labour and recording each man's performance is so much superior to the old day-work method of handling men, why is it not all that is required? Because no foreman can watch and study all of his men all of the time, and because any system of laying out and apportioning work, and of returns and records, which is sufficiently elaborate to keep proper account of the performance of each workman, is more complicated than piece-work. It is evident that that system is the best, which, in attaining the desired result, presents in the long run the course of least resistance.

17. The inherent and most serious defect of even the best managed day-work lies in the fact that there is nothing about the system that is self-sustaining. When once the men are working at a rapid pace, there is nothing but the constant unremitting watchfulness and energy of the management to keep them there ; while with every form of piece-work, each new rate that is fixed insures a given speed for another section of work, and to that extent relieves the foreman from worry.

18. From the best type of day-work to ordinary piece-work the step is a short one. With good day-work the various operations of manufacturing should have been divided into small sections or jobs, in order to properly gauge the efficiency of the men ; and the quickest time should have been recorded in which each operation has been performed. The change from paying by the hour to paying by the job is then readily accomplished.

19. The theory upon which the ordinary system of piece-work operates to the benefit of the manufacturer is exceedingly simple. Each workman, with a definite price for each job before him, contrives a way of doing it in a shorter time, either by working harder or by improving his method ; and he thus makes a larger profit. After the job has been repeated a number of times at the more rapid rate, the manufacturer thinks that he should also begin to share in the gain, and therefore reduces the price of the job to a figure at which the workman, although working harder, earns, perhaps, but little more than he originally did when on day-work.

20. The actual working of the system, however, is far different. Even the most stupid man, after receiving two or three piece-work "cuts" as a reward for his having worked harder, resents this treatment and seeks a remedy for it in the future. Thus begins a war, generally an amicable war, but none the less a war, between the workmen and the management. The latter endeavours by every means to induce the workmen to increase the output, and the men gauge the rapidity with which they work, so as never to earn over a certain rate of wages, knowing that if they exceed this amount the piece-work price will surely be cut, sooner or later.

21. But the war is by no means restricted to piece-work. Every intelligent workman realizes the importance, to his own interest, of starting in on each new job as slowly as possible.

There are few foremen or superintendents who have anything but a general idea as to how long it should take to do a piece of work that is new to them. Therefore, before fixing a piece-work price, they prefer to have the job done for the first time by the day. They watch the progress of the work as closely as their other duties will permit, and make up their minds how quickly it can be done. It becomes the workman's interest then to go just as slowly as possible, and still convince the foreman that he is working well.

22. The extent to which, even in the largest and best-managed establishments, this plan of holding back on the work—"marking time," or "soldiering," as it is called—is carried on by the men, can scarcely be understood by one who has not worked among them. It is by no means uncommon for men to work at the rate of one-third, or even one-quarter, their maximum speed, and still preserve the appearance of working hard. And when a rate has once been fixed on such a false basis, it is easy for the men to nurse successfully "a soft snap" of this sort through a term of years, earning in the meanwhile just as much wages as they think they can without having the rate cut.

23. Thus arises a system of hypocrisy and deceit on the part of the men which is thoroughly demoralizing, and which has led many workmen to regard their employers as their natural enemies, to be opposed in whatever they want, believing that whatever is for the interest of the management must necessarily be to their detriment.

25. The effect of this system of piece-work on the character of the men is, in many cases, so serious as to make it doubtful whether, on the whole, well-managed day-work is not preferable.

26. There are several modifications of the ordinary method of piece-work, which tend to lessen the evils of the system, but I know of none that can eradicate the fundamental causes for war, and enable the managers and the men to heartily coöperate in obtaining the maximum product from the establishment. It is the writer's opinion, however, that the differential rate system of piece-work, which will be described later, in most cases entirely harmonizes the interests of both parties.

27. One method of temporarily relieving the strain between workmen and employers consists in reducing the price paid for work, and at the same time guaranteeing the men against further reduction for a definite period. If this period be made sufficiently long, the men are tempted to let themselves out and earn as much money as they can, thus "spoiling" their own job by another "cut" in rates when the period has expired.

28. Perhaps the most successful modification of the ordinary system of piece-work is the "gain-sharing plan." This was invented by Mr. Henry R. Towne, in 1886, and has since been extensively and successfully applied by him in the Yale and Towne Manufacturing Company at Stamford, Conn. It was admirably described in a paper which he read before this society in 1888. This system of paying men is, however, subject to the serious and, I think, fatal defect that it does not recognize the personal merit of each workman, the tendency being rather to herd men together and promote trades unionism, than to develop each man's individuality.

29. A still further improvement of this method was made by Mr. F. A. Halsey, and described by him in a paper entitled "The Premium Plan of Paying for Labour," and presented to this society in 1891. Mr. Halsey's plan allows free scope for each man's personal ambition, which Mr. Towne's does not.

30. Messrs. Towne and Halsey's plans consist briefly in recording the cost of each job as a starting-point at a certain time; then, if, through the effort of the workmen in the future, the job is done in a shorter time and at a lower cost, the gain is divided among the workmen and the employer in a definite ratio, the workmen receiving, say, one-half, and the employer one-half.

31. Under this plan, if the employer lives up to his promise, and the work-

man has confidence in his integrity, there is the proper basis for coöperation to secure sooner or later a large increase in the output of the establishment.

Yet there still remains the temptation for the workman to "soldier" or hold back while on day-work, which is the most difficult thing to overcome. And in this, as well as in all the systems heretofore referred to, there is the common defect that the starting-point from which the first rate is fixed is unequal and unjust. Some of the rates may have resulted from records obtained when a good man was working close to his maximum speed, while others are based on the performance of a medium man at one-third and one-quarter speed. From this follows a great inequality and injustice in the reward even of the same man when at work on different jobs. The result is far from a realization of the ideal condition in which the same return is uniformly received for a given expenditure of brains and energy. Other defects in the gain-sharing plan, and which are corrected by the differential rate system, are:

(1) That is slow and irregular in its operation in reducing costs, being dependent upon the whims of the men working under it.

(2) That it fails to especially attract first-class men and discourage inferior men.

(3) That it does not automatically insure the maximum output of the establishment per man and machine.

32. Coöperation, or profit sharing, has entered the mind of every student of the subject, as one of the possible and most attractive solutions of the problem, and there have been certain instances, both in England and France, of at least a partial success of coöperative experiments. So far as I know, however, these trials have been made either in small towns, remote from the manufacturing centres, or in industries which in many respects are not subject to ordinary manufacturing conditions.

Coöperative experiments have failed, and, I think, are generally destined to fail, for several reasons. The first and most important of these is, that no form of coöperation has yet been devised in which each individual is allowed free scope for his personal ambition. This always has been and will remain a more powerful incentive to exertion than a desire for the general welfare. The few misplaced drones, who do the loafing and share equally in the profits with the rest, under coöperation are sure to drag the better men down toward their level.

34. The second and almost equally strong reason for failure lies in the remoteness of the reward. The average workman (I don't say all men) cannot look forward to a profit which is six months or a year away. The nice time which they are sure to have to-day, if they take things easily, proves more attractive than hard work, with a possible reward to be shared with others six months later.

35. Other and formidable difficulties in the path of coöperation are, the equitable division of the profits, and the fact that, while workmen are always ready to share the profits, they are neither able nor willing to share the losses. Further than this, in many cases, it is neither right nor just that they should share either in the profits or the losses, since these may be due in great part to causes entirely beyond their influence or control, and to which they do not contribute.

36. When we recognize the real antagonism that exists between the interests of the men and their employers, under all of the systems of piece-work in common use; and when we remember the apparently irreconciable conflict implied in the fundamental and perfectly legitimate aims of the two: namely, on the part of the men, the universal desire to receive the largest possible wages for their time, and on the part of the employers, the desire to receive the largest possible return for the wages paid, what wonder that most of us arrive at the conclusion that no system of piece-work can be devised which shall enable the two to coöperate without antagonism, and to their mutual benefit?

37. Yet it is the opinion of the writer that even if a system has not already

been found which harmonizes the interests of the two, still the basis for harmonious coöperation lies in the two following facts :—

First. That the workman in nearly * every trade can and will materially increase their present output per day, providing they are assured of a permanent and larger return for their time than they have heretofore received.

Second. That the employers can well afford to pay higher wages per piece, even permanently, providing each man and machine in the establishment turns out a proportionately larger amount of work.

The truth of the latter statement arises from the well-recognized fact that, in most lines of manufacture, the indirect expenses equal or exceed the wages paid directly to the workmen, and that these expenses remain approximately constant, whether the output of the establishment is great or small.

From this it follows that it is always cheaper to pay higher wages to the workmen when the output is proportionately increased, the diminution in the indirect portion of the cost per piece being greater than the increase in wages. Many manufacturers, in considering the cost of production, fail to realize the effect that the volume of output has on the cost. They lose sight of the fact that taxes, insurance, depreciation, rent, interest, salaries, office expenses, miscellaneous labour, sales expenses, and frequently the cost of power (which in the aggregate amount to as much as wages paid to workmen), remain about the same whether the output of the establishment is great or small.

38. In our endeavour to solve the piece-work problem by the application of the two fundamental facts above referred to, let us consider the obstacles in the path of harmonious coöperation, and suggest a method for their removal.

39. The most formidable obstacles is the lack of knowledge on the part of both the men and the management (but chiefly the latter) of the quickest time in which each piece of work can be done ; or, briefly, the lack of accurate time-tables for the work of the place.

40. The remedy for this trouble lies in the establishment, in every factory, of a proper rate-fixing department ; a department which shall have equal dignity and command equal respect with the engineering and managing departments, and which shall be organized and conducted in an equally scientific and practical manner.

41. The rate-fixing, as at present conducted, even in the best-managed establishments, is very similar to the mechanical engineering of fifty or sixty years ago. Mechanical engineering at that time consisted in imitating machines which were in more or less successful use, or in guessing at the dimensions and strength of the parts of a new machine ; and as the parts broke down or gave out, in replacing them with stronger ones. Thus, each new machine presented a problem almost independent of former designs, and one which could be solved only by months or years of practical experience and a series of breakdowns.

Modern engineering, however, has become a study, not of individual machines, but of the resistance of materials, the fundamental principles of mechanics, and of the elements of design.

42. On the other hand, the ordinary rate-fixing (even the best of it), like the old-style engineering, is done by a foreman or superintendent, who, with the aid of a clerk, looks over the record of the time in which a whole job was done as nearly like the new one as can be found, and then guesses at the time required to do the new job. No attempt is made to analyze and time each of the classes of work, or elements of which a job is composed ; although it is a far simpler task to resolve each job into its elements, to make a careful study of

* The writer's knowledge of the speed attained in the manufacture of textile goods is very limited. It is his opinion, however, that owing to the comparative uniformity of this class of work, and the enormous number of machines and men engaged on similar operations, the maximum output per man and machine is more nearly realized in this class of manufactures than in any other. If this is the case, the opportunity for improvement does not exist to the same extent here as in other trades. Some illustrations of the possible increase in the daily output of men and machines are given in paragraphs 78 to 82.

the quickest time in which each of the elementary operations can be done, and, then, to properly classify, tabulate, and index this information, and use it when required for rate fixing, than it is to fix rates with even an approximation to justice, under the common system of guessing.

43. In fact, it has never occurred to most superintendents that the work of their establishments consists of various combinations of elementary operations which can be timed in this way ; and a suggestion that this is a practical way of dealing with the piece-work problem usually meets with derision, or, at the best, with the answer "It might do for some simple business, but my work is entirely too complicated."

44. Yet this elementary system of fixing rates has been in successful operation for the past ten years, on work complicated in its nature, and covering almost as wide a range of variety as any manufacturing that the writer knows of. In 1883, while foreman of the machine shop of the Midvale Steel Company, of Philadelphia, it occurred to the writer that it was simpler to time each of the elements of the various kinds of work done in the place, and then find the quickest time in which each job could be done, by summing up the total times of its component parts, than it was to search through the records of former jobs, and guess at the proper price. After practicing this method of rate-fixing himself for about a year, as well as circumstances would permit, it became evident that the system was a success. The writer then established the rate-fixing department, which has given out piece-work prices in the place ever since.

45. This department far more than paid for itself from the very start ; but it was several years before the full benefits of the system were felt, owing to the fact that the best methods of making and recording time observations of work done by the men, as well as determining the maximum capacity of each of the machines in the place, and of making working-tables and time-tables, were not at first adopted.

46. Before the best results were finally attained in the case of work done by metal cutting tools, such as lathes, planers, boring mills, etc., a long and expensive series of experiments was made, to determine, formulate, and finally practically apply to each machine the law governing the proper cutting speed of tools ; namely, the effect on the cutting speed of altering any one of the following variables ; the shape of the tool (*i. e.*, lip angle, clearance angle, and the line of the cutting edge), the duration of the cut, the quality of hardness of the metal being cut, the depth of the cut, and the thickness of the feed or shaving.

47. It is the writer's opinion that a more complicated and difficult piece of rate-fixing could not be found than that of determining the proper price for doing all kinds of machine work on miscellaneous steel and iron castings and forgings, which vary in their chemical composition from the softest iron to the hardest tool steel. Yet this problem was solved through the rate-fixing department and the "differential rate," with the final result of completely harmonizing the men and the management, in place of the constant war that existed under the old system. At the same time, the quality of the work was improved, and the output of the machinery and the men was doubled, and, in many cases, trebled. At the start there was naturally great opposition to the rate-fixing department, particularly to the man who was taking time observations of the various elements of the work ; but when the men found that rates were fixed without regard to the records of the quickest time in which they had actually done each job, and that the knowledge of the department was more accurate than their own, the motive for hanging back or "soldiering" on this work ceased, and with it the greatest cause for antagonism and war between the men and the management.

48. As an illustration of the great variety of work to which elementary rate-fixing has already been successfully applied, the writer would state that, while acting as general manager of two

large sulphite pulp mills, he directed the application of piece-work to all of the complicated operations of manufacturing throughout one of these mills, by means of elementary rate-fixing, with the result, within eighteen months, of more than doubling the output of the mill.

The difference between elementary rate-fixing and the ordinary plan can perhaps be best explained by a simple illustration. Suppose the work to be planing a surface on a piece of cast iron. In the ordinary system the rate-fixer would look through his records of work done by the planing-machine, until he found a piece of work as nearly as possible similar to the proposed job, and then guess at the time required to do the new piece of work. Under the elementary system, however, some such analysis as the following would be made :

Work done by Man.	*Minutes.*
Time to lift piece from floor to planer table	——
Time to level and set work true on table	——
Time to put on stops and bolts	——
Time to remove stops and bolts	——
Time to remove piece to floor	——
Time to clean machine	——
Work done by Machine.	*Minutes*
Time to rough off cut ¼ in. thick, 4 feet long, 2½ ins. wide	——
Time to rough off cut ⅛ in. thick, 3 feet long, 13 ins. wide, etc.	——
Time to finish cut 4 feet long, 2½ ins. wide	——
Time to finish cut 3 feet long, 12 ins. wide, etc.	——
Total	——
Add —— per cent. for unavoidable delays	——

It is evident that this job consists of a combination of elementary operations, the time required to do each of which can be readily determined by observation. This exact combination of operations may never occur again, but elementary operations similar to these will be performed in differing combinations almost every day in the same shop.

A man whose business it is to fix rates soon becomes so familiar with the time required to do each kind of elementary work performed by the men, that he can write down the time from memory. In the case of that part of the work which is done by the machine, the rate-fixer refers to tables which are made out for each machine, and from which he takes the time required for any combination of breadth, depth and length of cut.

49. While, however, the accurate knowledge of the quickest time in which work can be done, obtained by the rate-fixing department and accepted by the men as standard, is the greatest and most important step towards obtaining the maximum output of the establishment, it is one thing to know how much work can be done in a day, and an entirely different matter to get even the best men to work at their fastest speed or anywhere near it.

50. The means which the writer has found to be by far the most effective in obtaining the maximum output of a shop, and which, so far as he can see, satisfies the legitimate requirements, both of the men and the management, is the differential rate system of piece-work. This consists, briefly, in paying a higher price per piece, or per unit, or per job, if the work is done in the shortest possible time, and without imperfections, than is paid if the work takes a longer time or is imperfectly done.

51. To illustrate :—Suppose 20 units or pieces to be the largest amount of work of a certain kind that can be done in a day. Under the differential rate system, if a workman finishes 20 pieces per day, and all of these pieces are perfect, he receives, say, 15 cents (7½d.) per piece, making his pay for the day $15 \times 20 = \$3$ (12 sh.) If, however, he works too slowly and turns out, say, only 19 pieces, then, instead of receiving 15 cents per piece he gets only 12 cents (6d.) per piece, making his pay for the day $12 \times 19 = \$2.28$ (9 sh. 1½d.) instead of $3 per day. If he succeeds in finishing 20 pieces, some of which are imperfect, then he should receive a still lower rate per day, say, 10 cents (5d.) or 5 cents (2½d.) per piece, according to circumstances, making his pay for the day $2 (8 sh.), or only $1 (4 sh.), instead of $3 (12 sh.).

52. It will be observed that this style of piece-work is directly the opposite of the ordinary plan. To make the difference between the two methods more clear, suppose, under the ordinary

system of piece-work, that the workman has been turning out 16 pieces per day, and has received 15 cents (7½d.) per piece, then his day's wages would be $15 \times 16 = \$2.40$ (9 sh. 7½d.). Through extra exertion he succeeds in increasing his output to 20 pieces per day, and thereby increases his pay to $15 \times 20 = \$3$ (12 sh.). The employer, under the old system, however, concludes that $3 is too much for the man to earn per day, since other men are only getting from $2.25 (9 sh.) to $2.50 (10 sh.), and therefore cuts the price from 15 cents per piece to 12 cents, and the man finds himself working at a more rapid pace, and yet earning only the same old wages, $12 \times 20 = \$2.40$ (9 sh. 7½d.) per day. What wonder that men do not care to repeat this performance many times?

53. Whether coöperation, the differential plan, or some other form of piece-work be chosen in connection with elementary rate-fixing, as the best method of working, there are certain fundamental facts and principles which must be recognized and incorporated in any system of management before true and lasting success can be attained; and most of these facts and principles will be found to be not far removed from what the strictest moralists would call justice.

54. The most important of these facts is, that men will not do an extraordinary day's work for an ordinary day's pay, and any attempt on the part of the employers to get the best work out of their men and give them the standard wages paid by their neighbours will surely be, and ought to be, doomed to failure.

55. Justice, however, not only demands for the workman an increased reward for a large day's work, but should compel him to suffer an appropriate loss in case his work falls off either in quantity or quality. It is quite as important that the deductions for bad work should be just, and graded in proportion to the shortcomings of the workman, as that the reward should be proportional to the work done. The fear of being discharged, which is practically the only penalty applied in many establishments, is entirely inadequate to producing the best quantity and quality of work, since the workmen find that they can take many liberties before the management makes up its mind to apply this extreme penalty.

56. It is clear that the differential rate satisfies automatically, as it were, the above conditions of properly graded rewards and deductions. Whenever a workman works for a day (or even a shorter period) at his maximum, he receives under this system unusually high wages; but when he falls off either in quantity or quality from the highest rate of efficiency, his pay falls below even the ordinary.

57. The lower differential rate should be fixed at a figure which will allow the workman to earn scarcely an ordinary day's pay when he falls off from his maximum pace, so as to give him every inducement to work hard and well.

58. The exact percentage beyond the usual standard which must be paid to induce men to work to their maximum, varies with different trades and with different sections of the country. There are places where the men (generally speaking) are so lazy and demoralized that no sufficient inducement can be offered to make them do a full day's work.

59. It is not, however, sufficient that each workman's ambition should be aroused by the prospect of larger pay at the end of even a comparatively short period of time. The stimulus to maximum exertion should be a daily one. This involves such vigorous and rapid inspection and returns as to enable each workman, in most cases, to know each day the exact result of his previous day's work, *i. e.*, whether he has succeeded in earning his maximum pay, and exactly what his losses are for careless or defective work. Two-thirds of the moral effect, either of a reward or penalty, are lost by even a short postponement.

60. It will again be noted that the differential rate system forces this condition both upon the management and the workman, since the men, while

working under it, are above all anxious to know at the earliest possible minute whether they have earned their high rate or not. And it is equally important for the management to know whether the work has been properly done.

61. As far as possible each man's work should be inspected and measured separately, and his pay and losses should depend upon his individual efforts alone. It is, of course, a necessity that much of the work of manufacturing—such, for instance, as running roll-trains, hammers or paper machines—should be done by gangs of men who coöperate to turn out a common product, and that each gang of men should be paid a definite price for the work turned out, just as if they were a single man.

In the distribution of the earnings of a gang among its members, the percentage which each man receives should, however, depend not only upon the kind of work which each man performs, but upon the accuracy and energy with which he fills his position. In this way the personal ambition of each of a gang of men may be given its proper scope.

62. Again, we find the differential rate acting as a most powerful lever to force each man in a gang of workmen to do his best; since if, through the carelessness or laziness of any one man, the gang fails to earn its high rate, the drone will surely be obliged by his companions to do his best the next time or else get out.

63. A great advantage of the differential rate system is that it quickly drives away all inferior workmen, and attracts the men best suited to the class of work to which it is applied, since none but really good men can work fast enough and accurately enough to earn the high rate; and the low rate should be made so small as to be unattractive even to an inferior man.

64. If for no other reason than the one that it secures for an establishment a quick and active set of workmen, the differential rate is a valuable aid, since men are largely creatures of habit; and if the piece-workers of a place are forced to move quickly and work hard, the day-workers soon get into the same way, and the whole shop takes on a more rapid pace.

65. The greatest advantage, however, of the differential rate piece-work, in connection with a proper rate-fixing department, is, that together they produce the proper mental attitude on the part of the men and the management toward each other. In place of the indolence and indifference which characterize the workmen of many day-work establishments, and to a considerable extent also their employers; and in place of the constant watchfulness, suspicion, and even antagonism with which too frequently the men and the management regard each other, under the ordinary piece-work plan, both sides soon appreciate the fact that with the differential rate it is their common interest to coöperate to the fullest extent, and to devote every energy to turning out daily the largest possible output. This common interest quickly replaces antagonism, and establishes a most friendly feeling.

66. Of the two devices for increasing the output of a shop, the differential rate, and the scientific rate-fixing department, the latter is by far the more important. The differential rate is invaluable at the start, as a means of convincing men that the management is in earnest in its intention of paying a premium for hard work; and it at all times furnishes the best means of maintaining the top notch of production; but when, through its application, the men and the management have come to appreciate the mutual benefit of harmonious coöperation and respect for each other's rights, it ceases to be an absolute necessity. On the other hand, the rate-fixing department, for an establishment doing a large variety of work, becomes absolutely indispensable. The longer it is in operation the more necessary it becomes.

67. Practically, the greatest need felt in an establishment wishing to start a rate-fixing department is the lack of data as to the proper rate of speed at which work should be done.

There are hundreds of operations which are common to most large establishments ; yet, each concern studies the speed problem for itself, and days of labour are wasted in what should be settled once for all, and recorded in a form which is available to all manufacturers.

68. What is needed is a hand-book on the speed with which work can be done, similar to the elementary engineering hand-books, and the writer ventures to predict that such a book will, before long, be forthcoming. Such a book should describe the best method of making, recording, tabulating, and indexing time-observations, since much time and effort are wasted by the adoption of inferior methods.

69. The term "rate-fixing department" has rather a formidable sound. In fact, however, that department should consist in most establishments of one man, who, in many cases, need give only a part of his time to the work.

70. When the manufacturing operations are uniform in character, and repeat themselves day after day—as, for instance, in paper or pulp mills—the whole work of the place can be put upon piece-work in a comparatively short time ; and when once proper rates are fixed, the rate-fixing department can be dispensed with, at any rate until some new line of manufacture is taken up.

71. The system of differential rates was first applied by the writer to a part of the work in the machine shop of the Midvale Steel Company, in 1884. Its effect in increasing and then maintaining the output of each machine to which it was applied was almost immediate, and so remarkable that it soon came into high favour, with both the men and the management. It was gradually applied to a great part of the work of the establishment, with the result, in combination with the rate-fixing department, of doubling and in many cases trebling the output, and, at the same time, increasing instead of diminishing the accuracy of the work.

72. In some cases it was applied by the rate-fixing department without an elementary analysis of the time required to do the work, simply offering a higher price per piece providing the maximum output before attained was increased to a given extent. Even this system met with success, although it is by no means correct, since there is no certainty that the reward is in just proportion to the efforts of the workmen.

73. In cases where large and expensive machines are used, such as paper machines, steam hammers, or rolling mills, in which a large output is dependent upon the severe manual labour as well as the skill of the workmen (while the chief cost of production lies in the expense of running the machines rather than in the wages paid), it has been found of great advantage to establish two or three differential rates, offering a higher and higher price per piece or per ton as the maximum possible output is approached.

74. As before stated, not the least of the benefits of elementary rate-fixing are the indirect results. The careful study of the capabilities of the machines, and the analysis of the speeds at which they must run, before differential rates can be fixed, which will insure their maximum output, almost invariably result in first indicating and then correcting the defects in their design, and in the method of running and caring for them.

75. In the case of the Midvale Steel Company, to which I have already referred, the machine shop was equipped with standard tools, furnished by the best makers, and the study of these machines, such as lathes, planers, boring mills, etc., which was made in fixing rates, developed the fact that they were none of them designed and speeded so as to cut steel to the best advantage. As a result, this company has demanded alterations from the standard in almost every machine which they have bought during the past eight years. They have themselves been obliged to superintend the design of many special tools which would not have been thought of, had it not been for elementary rate-fixing.

76. But what is, perhaps, of more importance still, the rate-fixing department has shown the necessity of carefully systematizing all of the small details in the running of each shop, such as the care of belting, the proper shape for cutting tools, and the dressing, grinding, and issuing same, oiling machines, issuing orders for work, obtaining accurate labour and material returns, and a host of other minor methods and processes. These details, which are usually regarded as of comparatively small importance, and many of which are left to the individual judgment of the foreman and workmen, are shown, by the rate-fixing department, to be of paramount importance in obtaining the maximum output, and to require the most careful and systematic study and attention in order to insure uniformity and a fair and equal chance for each workman. Without this preliminary study and systematizing of details, it is impossible to apply successfully the differential rate in most establishments.

77. As before stated, the success of this system of piece-work depends fundamentally upon the possibility of materially increasing the output per man and per machine, providing the proper man be found for each job and the proper incentive be offered to him.

78. As an illustration of the difference between what ought to be done by a workman well suited to his job, and what is generally done, I will mention a single class of work, performed in almost every establishment in the country. In shoveling coal from a car over the side on to a pile, one man should unload forty tons per day, and keep it up, year in and year out, and thrive under it.

With this knowledge of the possibilities I have never failed to find men who were glad to work at this speed for from four and a half to five cents per ton. The average speed for unloading coal in most places, however, is nearer fifteen than forty tons per day. In securing the above rate of speed it must be clearly understood that the problem is not how to force men to work harder or longer hours than their health will permanently allow; but, rather, first, to select among the labourers which are to be found in every community, the men who are physically able to work permanently at that job, and at the speed mentioned, without damage to their health, and who are mentally sufficiently inert to be satisfied with the monotony of the work, and then, to offer them such inducements as will make them happy and contented in doing so.

79. The first case in which a differential rate was applied furnishes a good illustration of what can be accomplished by it. A standard steel forging, many thousands of which are used each year, had for several years been turned at the rate of from four to five per day under the ordinary system of piece-work, 50 cents (2 sh.) per piece being the price paid for the work. After analyzing the job and determining the shortest time required to do each of the elementary operations of which it was composed, and then summing up the total, the writer became convinced that it was possible to turn ten pieces a day. To finish the forgings at this rate, however, the machinists were obliged to work at their maximum pace from morning to night, and the lathes were run as fast as the tools would allow, and under a heavy feed.

It will be appreciated that this was a big day's work, both for men and machines, when it is understood that it involved removing, with a single 16-inch lathe, having two saddles, an average of more than 800 pounds of steel chips in ten hours. In place of the 50-cent (2 sh.) rate that they had been paid before, they were given 35 cents (1 sh. 5d.) per piece when they turned them at the speed of 10 per day, and when they produced less than 10, they received only 25 cents (1 sh.) per piece.

80. It took considerable trouble to induce the men to turn at this high speed, since they did not at first fully appreciate that it was the intention of the firm to allow them to earn permanently at the rate of $3.50 (14 sh.) per

day. But from the day they first turned 10 pieces to the present time, a period of more than ten years, the men who understood their work have scarcely failed a single day to turn at this rate. Throughout that time, until the beginning of the recent fall in the scale of wages throughout the country, the rate was not cut.

81. During this whole period the competitors of the company never succeeded in averaging over half of this production per lathe, although they knew and even saw what was being done at Midvale. They, however, did not allow their men to earn over from $2 to $2.50 (8 to 10 sh.) per day, and so, never even approached the maximum output.

82. The following table will show the economy of paying high wages under the differential rate in doing the above job:—

COST OF PRODUCTION PER LATHE PER DAY.

Ordinary system of piece-work.		
Man's wages	$2.50 =	£0. 10. 0
Machine cost	3.37 =	0. 13. 6
Total cost per day	$5.87 =	1. 3. 6
5 pieces produced.		
Cost per piece	$1.17 =	£0. 4. 8½
Differential rate system.		
Man's wages	$3.50 =	£0. 14. 0
Machine cost	3.37 =	0. 13. 6
Total cost per day	$6.87 =	£1. 7. 6
10 pieces produced.		
Cost per piece	$0.69 =	£0. 2. 9½

The above result was mostly, though not entirely, due to the differential rate. The superior system of managing all of the small details of the shop counted for considerable.

83. There has never been a strike by men working under differential rates, although these rates have been applied at the Midvale Steel Works for the past ten years; and the steel business has proved during this period the most fruitful field for labour organizations and strikes. And this, notwithstanding the Midvale Company has never prevented its men from joining any labour organization. All of the best men in the company saw clearly that the success of a labour organization meant the lowering of their wages, in order that the inferior men might earn more, and, of course, could not be persuaded to join.

84. I attribute a great part of this success in avoiding strikes to the high wages which the best men were able to earn with the differential rates, and to the pleasant feeling fostered by this system; but this is by no means the whole cause. It has, for years, been the policy of that company to stimulate the personal ambition of every man in their employ, by promoting them either in wages or position whenever they deserved it, and the opportunity came.

A careful record has been kept of each man's good points as well as his shortcomings, and one of the principal duties of each foreman was to make this careful study of his men, so that substantial justice could be done to each. When men, throughout an establishment, are paid varying rates of daywork wages, according to their individual worth, some being above and some below the average, it cannot be for the interest of those receiving high pay to join a union with the cheap men.

85. No system of management, however good, should be applied in a wooden way. The proper personal relations should always be maintained between the employers and men, and even the prejudices of the workmen should be considered in dealing with them. The employer who goes through his works with kid gloves on, and is never known to dirty his hands or clothes, and who either talks to his men in a condescending or patronizing way, or else not at all, has no chance whatever of ascertaining their real thoughts or feelings.

86. Above all, it is desirable that men should be talked to on their own level by those who are over them. Each man should be encouraged to discuss any trouble which he may have, either in the works or outside, with those over him. Men would far rather even be blamed by their bosses, especially if the "tearing out" has a touch of human nature and feeling in it, than to be passed by day after day without a word, and with no more notice than if they were part of the machinery.

The opportunity which each man should have of airing his mind freely, and having it out with his employers, is a safety-valve ; and if the superintendents are reasonable men, and listen to, and treat with respect, what their men have to say, there is absolutely no reason for labour unions and strikes.

87. It is not the large charities (however generous they may be) that are needed or appreciated by workmen, such as the founding of libraries and starting workingmen's clubs, so much as small acts of personal kindness and sympathy, which establish a bond of friendly feeling between them and their employers.

88. The moral effect of the writer's system on the men is marked. The feeling that substantial justice is being done them renders them, on the whole, much more manly, straightforward and truthful. They work more cheerfully, and are more obliging to one another and their employers. They are not soured, as under the old system, by brooding over the injustice done them, and their spare minutes are not spent to the same extent in criticising their employers.

A noted French engineer and steel manufacturer, who recently spent several weeks in the works of the Midvale Company in introducing a new branch of manufacture, stated, before leaving, that the one thing which had impressed him as most unusual and remarkable about the place was the fact that not only the foremen, but the workmen, were expected to and did, in the main, tell the truth in case of any blunder or carelessness, even when they had to suffer from it themselves.

89. From what the writer has said he is afraid that many readers may gain the impression that he regards elementary rate-fixing and the differential rate as a sort of panacea for all human ills. This is, however, far from the case. While he regards the possibilities of these methods as great, he is of the opinion, on the contrary, that this system of management will be adopted by but few establishments, in the near future at least; since its really successful application not only involves a thorough organization, but requires the machinery and tools throughout the place to be kept in such good repair that it will be possible for the workmen each day to produce their maximum output. But few manufacturers will care to go to this trouble until they are forced to do so.

90. It is his opinion that the most successful manufacturers, those who are always ready to adopt the best machinery and methods when they see them, will gradually avail themselves of the benefits of scientific rate-fixing, and that competition will compel the others to follow slowly in the same direction.

91. Even if all of the manufacturers, who are competing in the same line of business, were to adopt these methods, they could still well afford to pay the high rate of wages demanded by the differential rate, and necessary to induce men to work fast, since it is a well-recognized fact the world over that the highest-priced labour, providing it is proportionately productive, is the cheapest ; and the low cost at which they could produce their goods would enable them to sell in foreign markets and still pay high wages.

92. The writer is far from taking the view, held by many manufacturers, that labour unions are an almost unmitigated detriment to those who join them, as well as to employers and the general public. The labour unions—particularly the trades unions of England—have rendered a great service not only to their members, but to the world, in shortening the hours of labour and in modifying the hardships and improving the conditions of wage-workers. In the writer's judgment, the system of treating with labour unions would seem to occupy a middle position among the various methods of adjusting the relations between employers and men.

When employers herd their men together in classes, pay all of each class the same wages, and offer none of them any inducement to work harder or do better than the average, the only remedy for the men lies in combination ; and

frequently the only possible answer to encroachments on the part of their employers is a strike. This state of affairs is far from satisfactory to either employers or men, and the writer believes the system of regulating the wages and conditions of employment of whole classes of men by conference and agreement between the leaders, unions, and manufacturers, to be vastly inferior, both in its moral effect on the men and on the material interests of both parties, to the plan of stimulating each workman's ambition by paying him according to his individual worth, and without limiting him to the rate of work or pay of the average of his class.

93. The level of the great mass of the world's labour has been, and must continue to be, regulated by causes so many and so complex as to be at best but dimly recognized. The utmost effect of any system, whether of management, social combination, or legislation, can be but to raise a small ripple or wave of prosperity above the surrounding level, and the greatest hope of the writer is that, here and there, a few workmen, with their employers, may be helped, through this system, toward the crest of the wave.

A FEW FACTS ABOUT FILES.

By Stephen Nicholson.

UNDER THE POWER PRESS.

OLD and extensively used as they are, few people to-day realize the varieties of uses to which files are put, or the enormous amount of money and time which has been expended in reaching the present state of development in their manufacture. Whilst marked success has attended a few efforts at file making, the larger majority of enterprises started in this line of business have proven utter financial failures in which one set of investors after another have left their money and gained little in useful knowledge from their experience.

The file was known long before the Christian era. As to-day understood, it is a bar whose surface is provided with one or more sets of cutting edges or teeth, and is used to groove, level off, smooth and otherwise dress the surface of all materials less hard than itself. The length section, shape, kind of teeth and their relative coarseness, are variations which are governed by the kind of work the file is designed to perform. An almost endless possibility for slight differences, the advantages of which are sometimes real and sometimes imaginary, has developed an actual variety of files, regularly manufactured, which is very great. Some of these varieties are used in very large quantities, while others are called for seldom and in but limited numbers. Briefly, the general process of file making is as follows :

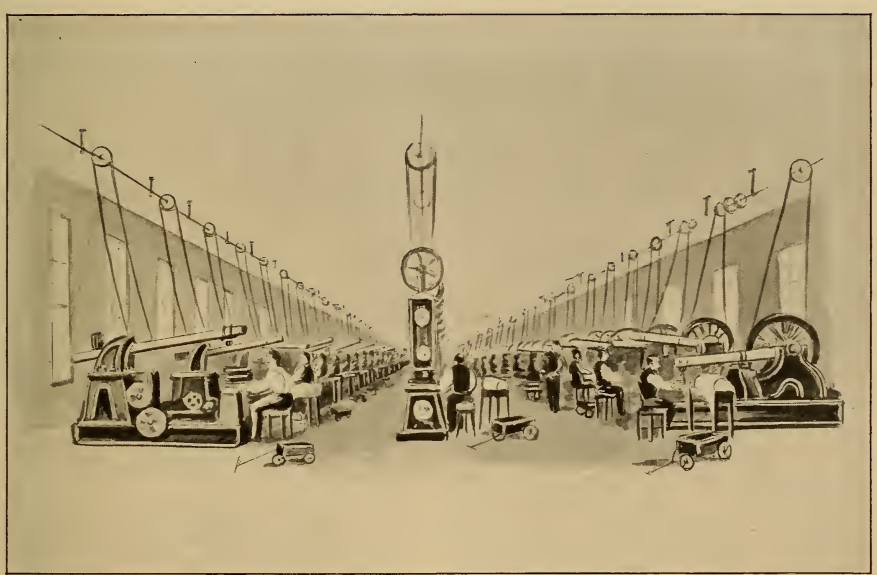
Bar steel is manufactured and rolled to the section of file desired. These bars are cut into suitable lengths, which bear a general proportion to the variations in size of the section. One end of each piece is shaped into what is called a "tang," designed to enter and fit a file handle. The other end of the piece of steel is usually pointed, or reduced in size, to give to the surfaces and edges more or less curvature. These two operations comprise what,

in general, is called forging, and the piece of steel now becomes known as a file blank.

To secure a uniform and soft temper, each blank is next annealed, which is done by heating, and then slowly cooling it. This is followed by the operation of grinding, in which the outside scale and imperfections are removed and a more perfect shape given to the file. The blank is then ready for forming the file teeth, which, in general, are made by striking a chisel into the surface, the chisel being held at an angle from the perpendicular, which operation, besides producing a depression, raises a sharp barb which forms the top of the teeth. When the file blank is suitably covered with teeth it is ready for tempering. This consists in heating the blank and plunging into suitable cooling baths, after which it is cleaned, oiled, and otherwise prepared to prevent rusting and to meet the requirements of customers.

These principal operations, viz.:— forging, annealing, grinding, cutting, tempering and finishing are the same for all files. They are subdivided and many minor operations are performed on each piece of steel before it becomes a finished file, making, in many cases, as many as fifty or sixty handlings. With little variation all files pass through these treatments, whether they be made by hand or by the various methods and machinery developed during the past generation.

Less than forty years ago, a large proportion of the files used in the United States were made in England, and most of the workmen, who did a limited and local business, were Englishmen. This does not mean that no development had progressed, but that no practical use had been made of such early improvements as had been worked out. Part of this was due to the limited and local character of much of the business ; but more was probably due to the opposition on the part of the skilled workmen in the file-making centres of England. There a system of farming out was in practice. The workman received his file blanks, or steel, once a week, and, taking them home, worked such hours as pleased him, and generally utilized the services



FORGING THE FILE BLANKS.

of wife and children. The clannishness and opposition to changes of any sort which this system created were sufficient to effectually prevent, for many years, the introduction of machinery, and it was not until the trade of the United States had been lost entirely that anything like a change of system was permitted. As most of the business in the United States was done by this same class of workmen, it will easily be seen how they were naturally at enmity with the early effort at improved methods and machinery. Various arguments were used to prove that files could not be made by machinery, and unfortunately this argument was given seeming color by the poor files made by some of the early manufacturers.

Probably no branch of business offered greater possibilities for gain from the introduction of machinery than did that of file making. The idea of having a machine to raise a file tooth, in place of doing it by the slow, labourious hand method, must have occurred to most thinking mechanics who saw a file cutter at work. The successful file-cutting machine was, however, a thing of slow development. To raise the proper kind of teeth, and to do this with all the variable angles and the many degrees of coarseness, or number of teeth per inch, was a complicated problem. To meet the accidental variations in shape caused by imperfect methods of preparing the blanks, and the great designed variation in shapes themselves, required a machine of great range and ready adaptability.

It was found, too, that the exactness with which machines worked produced a uniformity which had its disadvantages, and it became necessary to introduce elements of irregularity, especially in double-cut files, to prevent the teeth from standing in regular rows. To produce the best results, several types of machines were necessary, adapted to the various sections. A machine designed to cut teeth on the flat side of a file was not found to work well when used to cut rounds, etc.

The development of file-cutting machines was accompanied by improvements in machinery for grinding and forging, and by the invention of a machine to drawfile. Appliances for saving labour and securing uniformity of results were introduced throughout the entire process. Many of these were practical only when large quantities of files were handled at a time, and the needs of which appeared only as the business developed.

The investment of a very modest sum sufficed to equip a hand shop to make and recut files. No very large amount of working capital was needed, the business in new goods being almost

CUTTING FILES BY HAND.

THE OLD WAY OF FORGING FILES.

entirely done on order and largely to sample. With the creation of larger plants, to manufacture by machinery, came the need of establishing more uniformity to make possible the manufacturing in large quantities. The standardizing of sizes of steel, names, cuts and coarseness was opposed for a long time by the various manufacturers themselves. For years files were sold and discounted from an English price list made on the cost of producing by hand. After a time the advantage of a new list was seen and an American list was made, intending to be more in proportion with the cost of making and with the conditions of the United States. The method of earlier days of making to sample has, however, left many kinds of files still used which might be eliminated, and for which other styles and sizes might be substituted, made in quantity and with improved appliances.

To enter into any detailed description of the various machines and process which may be considered the best to-day for treating steel and making files, would be a long and tedious argument, and interesting to file makers more than to others. These, however, represent a great amount of labour and experiment. For the great public who use files, some points ought to be well understood and utilized to enable an intelligent criticism to be exercised.

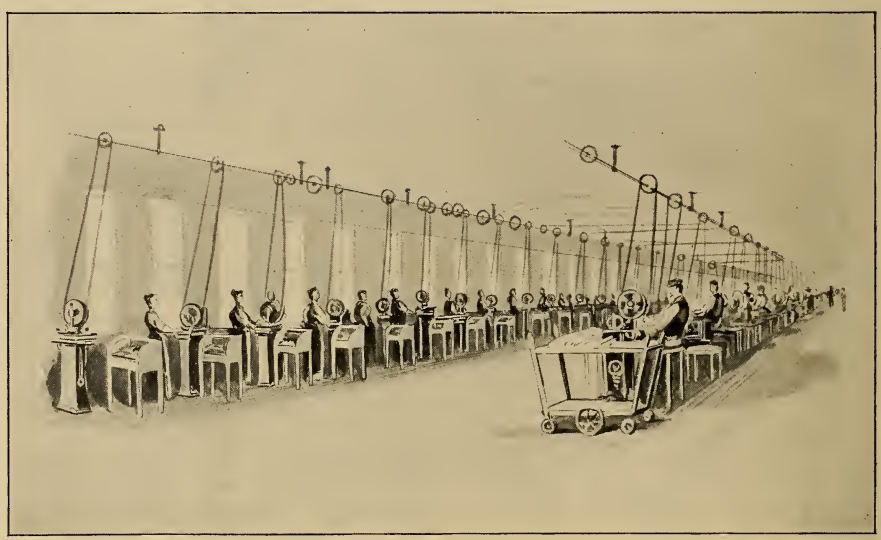
First. The average user of a file is not taught what makes a file, what files are regularly made and what money difference exists between a good file and a poor file. Some intelligent use of the file lists and catalogues would help here very much. For the difference between a poor, or fair, article and a good one, the real merits should be sought out. It is easy for a salesman anxious to dispose of his goods to represent and claim everything. Does the file answer the reasonable points of necessity for a good one? Are its teeth well shaped and sharp? Is it hard and sound? Is it straight and well shaped? Of a dozen files, are they uniform? Has the manipulating of the steel been such as to secure durability and wear for the cutting edge? Is the style and size of file selected the best for the work?

Second. With from 50 to 60 handlings the opportunity exists to omit some, slight others and in general to do what is called cheapen the cost of pro-

duction. It is well to remember that between the file maker and the file user there are often several who measure values only by the money involved, and that except in special cases a manufacturer will produce only to the extent for which he is paid. The honest file maker may try to educate the customer as to what is the truly cheapest, but the customer with his criticism and the price he will pay, fixes ultimately the quality which the manufacturer can produce.

industry as a whole, there are to-day several large plants in operation, giving employment to many hundred workmen and producing over one hundred thousand files daily, varying from those requiring two workmen to operate to files as small and delicate as a needle, and on which the teeth are so fine and numerous as to require a magnifying glass to distinguish one from the other.

Large capital is invested in special appliances and machines, and much of the work is done by men who become



MACHINE FILE CUTTING.

File making now represents an investment of a most formidable sum. In the United States a few of the old hand shops still struggle, and beside them are to be found small shops partially fitted with machines, where one investor after another learns how to make files at a greater cost than the selling price. Of the larger enterprises, with one exception, those started at or about the time of the American Civil War have disappeared entirely or changed hands, and nothing remains for the original investor. As a result of the development, however, of the skilled only after years of practice. Opportunity still exists for improvements and the simplifying of the business. The day for manufacturing with limited facilities and in small quantities has passed. The advantages of systems and special tools has become too apparent, and with the introduction of grinding machines and special machinists' tools, many old uses for files were done away with. As an offset, many new uses have appeared, and files are now probably as staple and unvarying an article as is to be found amongst the product of man's ingenuity.

HOW TO TEST A TURBINE.

By Samuel Webber.

THE editor's recent inquiry, "How to test a turbine," came to me most opportunely, for it reached me at the time when I had just finished re-examining and recalculating the heaviest turbine test I ever made, and one of the heaviest that ever was made, *i. e.*, of a large turbine in a cotton mill, giving 472 horse-power under a head of 29½ feet, and over 80 per cent net effect from the water used.

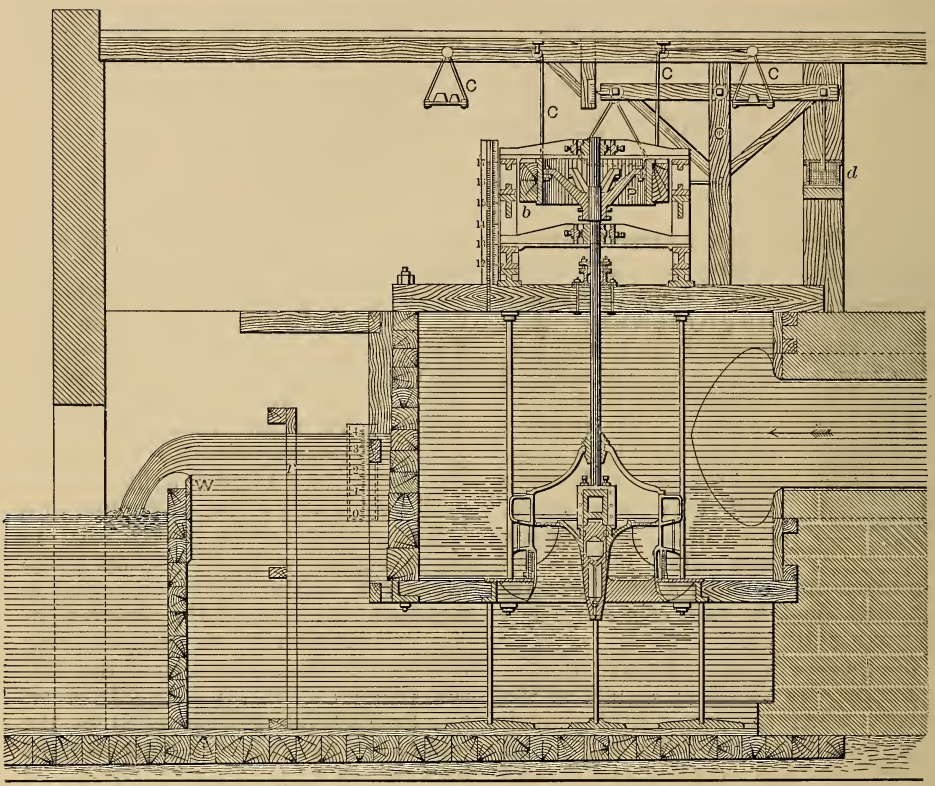
The owners of the mill were not satisfied with the practical results of the wheels, when the two wheels which were expected to drive the mill under 32 feet head, did not do it, and a third "spare wheel" had to be called on, and my advice was asked in the matter. I accordingly looked up my old note books and went over the matter again, finding no error in my original calculations, but, instead, finding the real cause of their trouble, in the insufficiency of the tail race to carry away the water from the wheels.

The wheel I tested used a little over 10,000 cubic feet of water per minute at the test, which, under the full head of 32 feet, would have been about 10,500 cubic feet, or 21,000 for the two wheels, and 31,500 for the three. The tail race was 30 feet wide, but the water had to pass through an arch under a railway, only 25 feet wide, about 100 feet below the mill, and the consequence was that the water was set back on the wheels, so that the head was only 29½ feet, the same as made by my weir at test, and the power realized consequently the same, or only 470 horse-power, instead of 530, which it should have been for each wheel.

So much for preliminaries. Engineers know what a Prony brake is, and that it is the usual instrument for determining the power given off by any prime motor, such as a water-wheel or steam engine. To those who are not engineers, let me say that it is the simple application to a friction pulley, placed on the shaft of a wheel or engine, of a brake, similar to the brakes used to check a train on a railroad, by which the speed of the wheel or engine is regulated according to the pressure applied to the brake. This pressure being known and the revolutions of the friction pulley counted, it is easy to ascertain the foot pounds controlled by the brake, and from them to determine the horse-power.

This form of testing apparatus derives its name from an eminent French engineer, Prony, who applied it for such purposes somewhere about the end of the last, or the beginning of the present, century. The principle of it is that a weight, held out steadily at the end of a horizontal lever, by the friction of a pulley, which is clasped by jaws at the other end of the lever, is the same as if the weight were lifted at the speed at which the point of attachment would rotate, if the weight did not hold it stationary.

It follows that a weight of 10 pounds hung on a lever 5 feet and 3 inches long, or the radius of a circle measuring 33 feet in circumference, if held up steadily by a friction pulley at a speed of 100 revolutions per minute, would be equal to 33 x 100 x 10, or 33,000 foot pounds, or one horse power. From this basis the power of a turbine is ascertained. We must have a suitable fric-



VERTICAL SECTION OF TURBINE PLANT WITH TESTING APPARATUS APPLIED.

tion pulley, a brake lever with its clamp and bolts, the necessary weights and a timing watch. In addition to these, a hydraulic regulator, or "dash-pot," to steady the motion, first introduced by the late Uriah A. Boyden, and the apparatus for lubricating and cooling the pulley, are necessary.

I can find no better illustrations of the apparatus used for testing a turbine on a vertical shaft than the accompanying ones, from the Journal of the Franklin Institute, of that used by the late James B. Francis to test a Swain wheel at the Boott mills at Lowell, Mass., U. S. A. In these

P is the friction pulley,
b is the brake,
c are counterbalances to take the load of the brake off from the wheel shaft,
l is the bent lever or scale-beam for transferring horizontal motion to a vertical lift,
S is the scale-pan for the weights.
d, the dash-pot,
w, the weir for measuring the water, and
r, the rack for smoothing the water after leaving the wheel.

I copy this illustration as representing the simplest and easiest form of brake procurable and as effective for all moderate powers, say up to 300 H. P., as any more expensive form made of metal, although in the test of the 500 H. P. wheel, above referred to, the brake was made of two sheets of boiler iron, each nearly a semi-circle, and hinged together so as to almost clasp the pulley. These were lined with wood. One end of one of them was

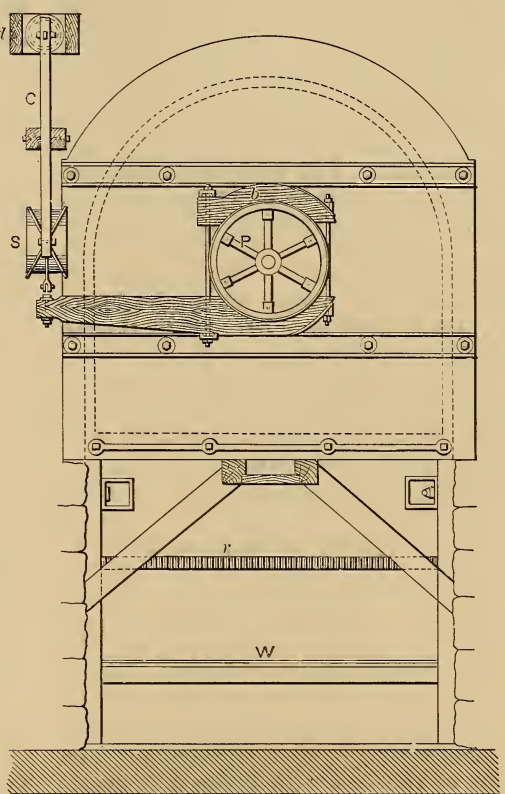
bolted to the brake lever, and the free end of the other was drawn up to it by an eye-bolt with a powerful screw cut on it, which passed through the lever and through a nut cut in a gear, which, in turn, was operated by a pinion on a hand-wheel shaft.

In the illustration the brake was closed by the nuts shown on the two bolts passing through it. These were screwed up by a long wrench, and this is usually sufficient. It will also be noted on an examination of the cuts that the arms of the friction pulley are not cast in one piece with the rim, but are a separate "spider," bolted to lugs on the inner surface of the rim. This is to prevent fracture of the pulley by expansion of the rim from heating, which is common in a long or heavy test, although it may be obviated, to a great extent, by the use of strong, "ropy" soapsuds as a lubricant, instead of oil, and the continuous application of a thin jet of cold water to the wheel in the openings left by the jaws of the brake. This dilutes the thick soapsuds, and has proved, by many years' experience, far the most satisfactory friction lubricant for wood upon iron that the writer has ever tried.

The pulley should, if possible, be a flanged one, so that the brake may fit into it as into a saddle; if not, the brake must have side flanges, so as not to slip off the pulley sidewise. The rim of the pulley must be thick and strong enough to sustain a pressure of at least 50 pounds per square inch when in motion, and the writer has put them to a strain as high as 75 pounds per square inch, though he would not advise it, as so high a pressure is difficult to lubricate properly and handle steadily.

In preparing for a turbine test, the pulley is the first thing to be secured, and the rule usually adopted by this writer is to ascertain first, approximately, the power to be transmitted and the revolutions per minute of the shaft of the wheel. He has found that 2750 ft.-lbs. per second, or 5 H. P., can be safely handled for every square foot of pulley surface moved one foot per second, or that a pulley containing 10 sq. feet of surface, or 3 3-16 feet diam. by 1 ft. face, at 100 revolutions per minute, or 16⅔ ft. per second, will be sufficient to control 83⅓ H. P. The writer has gone as high as 9 H. P. per square foot of surface per second. A pressure of 5 H. P., or 2750 lbs., is equal to 19 lbs. friction per square inch, or, if the friction be taken at 50 per cent., to 38 ft. per sq. in. pressure at about which Mr. Francis' "Swain wheel tests" were made. It will be perfectly safe, however, to add ¼ to this load, or to say that such a pulley at such a velocity would test 100 H. P.

The next point is the brake, which,



A TOP VIEW OF THE PLANT SHOWN ON THE OPPOSITE PAGE.

as shown in the cut, should, with its shoe, clasp the pulley from opposite sides, letting each bear on from ¼ to ⅓ of the circumference. This leaves two open spaces for the cooling water to be applied. The lubricant, of which I have already spoken, should be constantly fed on from a can holding from 1 to 2 gallons, and kept supplied by an attendant. This can should be supported on the brake with a pipe leading to the interior face, at the point where the pulley enters, and then by a set of "herring bone" grooves, spread over the whole face of the pulley, but which should not cut through the outer edge of the rim. The pipe from this can should be about ⅜ in. in diameter and supplied with a valve by which the flow of the lubricant can be regulated. A stream of the size of a goose-quill will do for a small pulley, or of a lead pencil, for a pretty large one, with the aid of the water thrown in at the openings.

The writer has tried metallic brakes and oil, but does not like them, and if they are made of a flattened tube, with a water circulation, they are very expensive, and inaccessible for all ordinary practice. An iron pulley, a wooden brake and plenty of soap are always to be had, and the most convenient in use.

The brake should be made of some sound, strong timber. The writer prefers white oak or rock maple, and the bolts which draw it together should have square heads, countersunk in the "shoe," to keep them from turning round when the nut is screwed up. The size of timber for the brake may be determined by the formula in any engineer's pocket book for a beam loaded at one end.

The length of the brake lever is a matter worthy of serious consideration, for a little forethought here will save a great many figures in computation and the liability of many errors. This does not seem to have occurred to the early experimenters, for I find in Mr. Francis' "Tests of the Tremont turbine" that the length of his lever was 9.745 ft; the vertical arm of his bell crank side beam was 4.50 ft. and the horizontal one 5 ft., making the real radial length to which the weights were applied 10.827778 ft. In his Swain tests the brake lever was 10.760 ft. and the bell crank arms 5 ft. and 4.495 ft. respectively, making the length to be used in calculations 11.969 ft. Mr. Mills, in his tests of the Swain wheel, gives the following dimensions: Brake lever, 8.164 ft.; bell crank, 4.4955 vertical, and 5.0027 horizontal, making effective length 9.085 ft. and circle of said radius 57.083 ft.

All these odd lengths and extra decimals make the calculations from them very tedious, and the writer has adopted the plan of making his brake lever equal to the radius of a circle, which should represent an integral part of a horse-power, *i. e.*, either 33, 66 or 99 ft., if the count be taken in revolutions per minute, or of 55 ft. if the number of seconds occupied in making 100 revolutions be counted. These lengths of radius are:

For a 33-ft. circle,	5 ft.	3.024″
" 66 "	10 "	6.048″
" 99 "	15 "	9.072″
and for 55 "	8 "	9.042″

For all practical purposes these decimals of an inch, being all less than one-tenth, may be safely disregarded. Mr. Francis once said to me in regard to these matters, "What is the use of wasting time in elaborating the decimals of one per cent. to 3 or 4 figures, when the daily atmospheric changes in a cotton or woolen mill, or machine shop, affect belts, bands and lubricants, so as to vary the power required from 5 to 10 per cent. every day?"

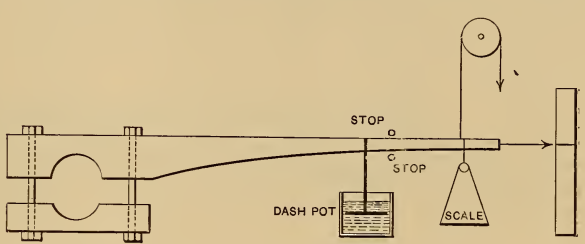
Although accuracy is the soul of engineering, there is no use to waste time and money in pursuing it to a point where it is utterly worthless. Therefore, I adopt now, where possible, the length of brake levers stated, and if a bell crank be needed, as in a vertical wheel, I make the arms either of equal length, or as two to one. Then, if the revolutions per minute of a 33-ft. circle are taken, multiply their number by the weight in the scale, strike off 3 decimals and you have the horse-power; multiply that by 2 or 3, if you use a 66 or a 99-ft. circle. If the 55-ft. circle be

most convenient, take the number of seconds occupied in making 100 revolutions and divide the pounds in the scale-pan by them ; multiply the result by 10 and you have the horse-power at once. Make your machinery do its own calculation, and you will save fatigue and error.

The speed of the shaft is best ascertained by the automatic speed counter, consisting of a short worm shaft, with a gear of 100 teeth, which strikes a bell at every 100 revolutions of the shaft. This can be tapped into the end of the wheel shaft, and the plate which holds the bell kept from turning round by a wire tied to any convenient stay. Have your weights clearly marked beforehand in black on white, or white on black, so that you can see at once what weight you have on the scales.

The dash-pot, or regulator, is to steady the motion, and consists of either a cylinder or a square box, filled with water, and fastened to some support under the scale-beam, so that a piston, one-eighth inch less in diameter than the box, may move freely up and down in it, except for the resistance of the water. A very good proportion for this is one square inch area for each horse-power to be controlled. The dash-pot may be at the opposite end of the scale-beam from the weight pan, and may help to balance it, but there are occasions in which it is impossible to use a beam like this, and the form of a bell-crank has to be adopted. In such a case it may be placed on the same side as the weights, and the whole balanced off by a weight over a pulley hung from the floor above.

A wheel on a horizontal shaft only needs the leverage of the brake itself, which should be balanced off in the same way when all is ready, before testing, with the scale-pan hung on, the piston also hung, and in the dash-pot filled with water, so that the whole apparatus, exactly as it is to be used, is perfectly balanced before commencing operations. On the horizontal shaft the lift will, of course, be perpendicular, but the knife-edged eye bolt, from which the scale is hung, should stand exactly level with the centre of the shaft. With the vertical shafts the line of pull on the scale-beam should be exactly perpendicular to a line drawn from the centre of the shaft to the eye bolt on which the weight is hung. With the apparatus on a vertical shaft the weight of the friction pulley will usually be about equal to that of the bevel-gear, whose place it takes, but the brake should be suspended, so that its weight will not bear on the wheel-step, and a rope should also support the extreme end of the lever, particularly if it is a long one, and be attached to a hook or bolt



MAKING THE ADJUSTMENTS.

directly over the eye bolt when in a working position, so as not to give any lateral strain on the lever.

The brake on a horizontal shaft should be lifted off of the pulley after all the adjustments of position are made and balanced over an edge, with all its appurtenances, and the piston in water in the dash-pot. This is done by a weighted rope or band passing over a pulley above, and this pulley should be large enough and move freely on its axis, so that a spirit level, placed centrally over the point of balance on the pulley, will show the least weight added to the end of the lever. All pivots taking a strain should be "knife-edged," like the fulcrum of a steelyard.

The extreme end of the scale-beam should be provided with a pointer, working against a board on which a black line on white, or *vice versa*, shows

the exact point of level, and strong stops must be placed above the scale beam, and also below, so as to prevent it from moving more than three or four inches from the line. This line should be in clear sight of the "man at the helm," or the one who operates the screws of the brake, and he should aim to keep the pointer on the line, and all tests should be rejected in which the lever rests on either stop.

I have spoken of length of brake lever, and recommended a radius which would give a circle, of which the circumference would be the integral part of a horse-power. If you cannot do that, get, if possible, the radius of a circle of even decimals of feet, say 20, 30, 40, etc. It is much easier to make your lever the radius of an even circle, to start with, than to make it even feet, and have to multiply it by 3.1416, and use a lot of decimals in all your future calculations. You will sometimes have to yield to the circumstances of the situation, as the writer did in the case of the heavy test just spoken of, where he tried to get the radius of a 99-foot circle, but was obliged by a lot of iron columns and beams to use one of 14 ft. 9½ in., or the radius of a circle of 92.941 ft., and had these decimals to handle at every calculation. As his best test was made with 1082.5 lb. in the scale, at a speed of 400 revolutions in 315 seconds, or 76.19 revolutions per minute, the number of superfluous decimals to be handled is readily seen.

With all these points adjusted, if the test is for power only, we are ready. One man must handle the wrench at the brake, with his eye on the scale beam pointer, and so control the piston as to keep it on the level line ; another assistant must attend to the lubrication, and keep a steady flow of soap and water on the pulley; while the observer, having placed a certain weight in the scale, must time the revolutions of the shaft, and while he does this, he must also keep one eye on the pointer at the scale beam, to be sure that the brake is working properly.

The writer usually gets the proposed revolutions of the shaft, and the assumed power of the wheel, beforehand, and from them calculates the necessary weight in the scale to produce such result. He then begins by placing in the scale a weight, say 25 per cent. less than the one assumed, and counts the revolutions, and if they are too high, adds 5, 10, 15 or 20 lbs., as may be, to the load, and repeats this until the best point is passed, and the power decreases. This best point may be at the speed recommended by the builder, or it may not ; the writer has found it uncertain. If the scale beam, as advised, represents the integral circle of 1 H. P., the calculations necessary to determine results are very easily and rapidly made as the test goes on, and when the best point is closely ascertained, a more definite result may be reached by less changes of the weight, and very careful noting of speed to half seconds.

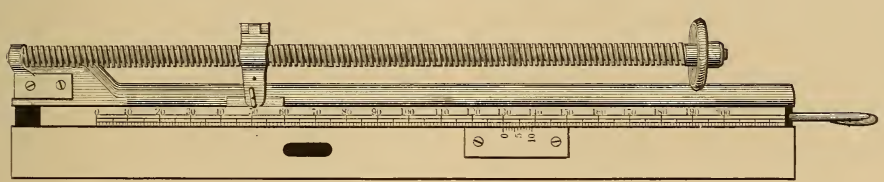
With these instructions and precautions the writer believes he has covered all the points necessary, if the actual working power of the wheel is all that it needed, but if the consumption of water and "net effect" are also desired, the following additional steps must be taken. A weir must be built across the tail race, far enough below the wheel to ensure still or quiet water, and if not so within a short distance, it may be obtained by passing the water through a rack, as shown in the illustration on page 606. This weir should have a sharp and level crest, say ⅛ in. thick, with end pieces of the same, set perpendicularly, an even number of feet apart, and all bevelled away on the down-stream side, so that the water touches only the up-stream edge.

This weir, according to Mr. Francis, should be of such height that the depth of the water in the race above it should be at least three times that of the body passing over the weir, and there should be a clear fall over it, so as to admit of a free passage of air under the sheet ; beyond this, the depth of the fall makes no difference. The depth of the water on the weir is not measured at the weir itself, but preferably by a pipe taken out from above the weir, and

leading into a box below, in which a hook gauge is set.

This, as shown in the illustration on this page, consists of a bronze or copper rod, from 2 to 3 feet long, having a needle-pointed steel hook at its lower end. It is graded in feet and hundredths, from zero at the upper end down to the point where the hook is attached. A vernier, fastened to the board to which the gauge is attached, enables the reading to be taken to thousandths of a foot. This board should be supported in a proper position, at such a height that, with the point of the hook just level with the top of the weir, the zero of the rod should agree with that on the vernier.

Then, when it is raised, so that the point of the hook just dimples the surface of the water, the depth of the water is read at the vernier. This was the



A HOOK GAUGE.

invention of Uriah A. Boyden, to avoid errors from capillary attraction. The level of the water in the box will agree with that above; or, the box, having a perforated bottom, may be inserted in the channel above, at least 6 feet above the weir. At the Holyoke testing flume, the hook gauge is permanently set below the weir with its point on an exact level with the top of the weir, and the water is brought from above through a flexible pipe into a tin can, supported by cords over pulleys, which can be raised to agree with the height above, so that the water will be nearly at the top of it, and the hook-gauge raised until its point just breaks the water, which in this way can be seen very distinctly.

Mr. Francis, in his "Hydraulic Experiments," gives a full table of the cubic feet of water per second passing over a weir, 1 foot long, at all depths below 3 feet, without contractions, and from this have been computed the cubic feet per minute over weirs of various lengths with end contraction up to 20 feet for all depths below 2 feet. These calculations the writer has carefully examined, and having found them to be reliable can recommend them. They are published by James Emerson, Willimansett, Mass., in his "Hydrodynamics," which also contains Mr. Francis' tables above noted, and valuable tables of the velocity of water under heads up to 500 feet.

Another observer is necessary at this hook-gauge, who should ascertain the depth of water passing over the weir every half minute while the power tests are being made, and the watches of both observers should be set together, so that the proper calculations may be made correctly. The end-pieces which determine the length of the weir should also be set out a foot or more from the walls of the race, so as to ensure perfect contraction, without side friction. Should there be any decided velocity in the water approaching the weir, an addition must be made for that, but as this is not a treatise on hydraulics, the writer will only refer to the well-known formulæ of Mr. Francis, merely saying that Mr. Francis found a velocity of approach of 6 inches per second to give an increase of volume of 1 per cent., and a velocity of 1 foot per second of 2 per cent. If the books referred to are inaccessible, it is well to remember that nearly all the turbine builders now publish rules and tables for measuring water in their catalogues. Should the flume gates leak, or there be any other waste water flowing over the weir, the height on the weir of this water must be first taken, and the volume ascertained from

the tables to be deducted from the final result. It will not be correct to subtract the height and calculate from the remainder.

When the volume of water per minute or second has been ascertained from the weir tables, multiply this by the height of the fall, and, again, by 62⅓ lbs. for the weight of each cubic foot of water, which is more near the average weight than the 62½ lbs. usually assumed. Divide the total by either 33,000 or 550, as the flow is taken in minutes or seconds respectively, and you have the gross horse-power of the water. By this divide the power attained by the turbine, and you have the net effect of the wheel.

Finally, to get the actual head on the wheel, a very convenient plan is to get a tin can 3 or 4 inches diameter and a foot long, with a bottle neck. Into this fasten securely, and so as to be air-tight, a slender pine rod 1 inch wide, and ¼ inch thick, and a little longer than the height of the fall. Drop this into still water perpendicularly so it will float. Mark the line of floatation, and from that graduate the rod upward in feet, numbering each foot, and for the last few feet near the top, or head water level, subdivide each foot into graduations of tenths and hundredths. Make a wooden box, a little larger than the can, open at each end, and a little longer than the depth of water in the pit. Nail slats across the bottom, so that the can will not fall through, and fasten this to the side of the pit, so as to go well below dead-water level. Drop the can into this with the rod coming up through the floor into the wheel room Tap a pipe into the feeder or forebay, with a flexible connection and a glass tube, a foot or more long at the end of it, and place this glass tube by the side of the float rod. The graduations on the rod, against which the water level from the forebay in the glass tube stands, will give the exact head acting on the wheel when running. The writer has put in a number of these "head-gauges" in various mills, and in almost every case the mill owners have kept them in place as a correct record of the head acting on their wheels at any time.

There is but one thing more to be said :—In making such a test your weir has, of course, reduced the normal head on the wheel, and to get the final result to the mill owner, the weir must be taken away, and the head taken under usual conditions. From the velocity tables referred to, calculate the volume of water which would pass under the full head; multiply this by the real head, and, again, by 62⅓ for the gross power of the water, and take the same percentage of net effect of that which you have found by your test, and you will get the real value of the wheel to the mill owner. In the case to which I referred at the outset, the mill owner, under the full head which he expected, would have really got 534 H. P. instead of 472 from each wheel.

Contingencies may arise, in which none of the suggestions made above will be available, but an ingenious mechanic will usually be able to find some way to accomplish the desired result. The writer once had to test a turbine from a horizontal shaft, running close under a floor, with no cellar room below, and had to cut a hole through the floor, and set his brake lever perpendicularly above the shaft, and then pull on a "bell-crank" scale-beam! He hopes, however, that the article may prove of value to the younger members of the profession.

Letters to the Editor.

PREVENTING ELECTROLYSIS OF UNDERGROUND PIPES.

I HAVE read with interest Mr. I. H. Farnham's article upon the electrolytic corrosion of gas and water pipes, in the August number of CASSIER'S MAGAZINE. The scheme he suggests, however, is merely an adaptation of Edison's feeder system, which is all right for the purpose of electrical distribution, but is of little or no value in preventing electrolysis.

The insertion of the graduated dead resistances advised by Mr. Farnham would cause a very heavy loss of current to the railway and require a serious increase of motive power. The resistances placed near the power-house would move the corroding points on the pipes farther away and scatter the damage over a wider area, while the more distant resistances would cause a greater current flow to the pipes.

Every practical railway man knows that it is simply impossible to balance the rapidly varying load of an electric railway power-house. Even were it possible, the rails are in contact with the same moist earth which surrounds the vast network of pipes, and the latter is, therefore, bound to share the current as long as the former are used for conductors, as is indicated in Figure 1: In this, *A* and *B* represent the dynamos, whose outgoing or positive poles *d* are connected to the trolley wire *T*. The current, as shown by the arrows, passes along the trolley wire, through the trolley pole and motors to the rails *R*. Here it has a choice of returning by the rails or by passing through the earth at *r r*, near the ends of the lines, along the pipe *P* and again through the earth to the rails at *t*, near the power-house, where the pipe is corroded.

If Mr. Farnham's advice was followed even to the extent of making the return wires equal in conductivity to both rails and pipes, the latter two would still carry about half the current. Some of the details suggested in a former article are merely sources of trouble. I understand that he advised the Water Board at Poughkeepsie, N. Y., U. S. A., to protect their pipes by inserting into them copper or brass contact plugs, and by carrying a wire from these plugs back to the negative terminal of the dynamos. Gas engineers know from experience that these plugs will set up a galvanic action on their own

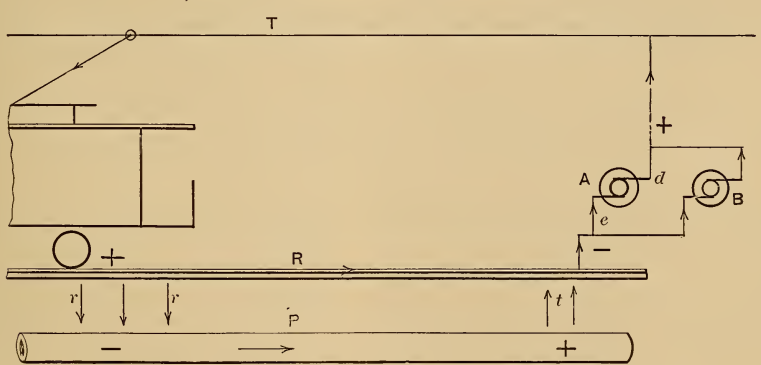


FIG 1 DIAGRAM OF CURRENT FLOW ON ELECTRIC RAILWAYS.

account which will soon destroy their contacts and will ultimately puncture the pipe.

An iron band, clamped on a lead ring around a pipe, is also a bad form of contact and certain to rust even though covered with tape and cement. Four such bands, each about three inches wide, on a 28-inch gas pipe, directly in front of a large railway power-house, and soldered to copper wires aggregating two square inches in section, leading to the negative terminals of the dynamos, still left the pipe six-tenths of a volt positive to the rails. Two of the lead bands had been put on within six months ; no acid was used in the soldering, and, yet, the lead was badly corroded and the pipe marked.

This shows plainly that the old scheme of connecting pipes to the negative pole of the dynamo, as advocated by Mr. Farnham, gives but slight and temporary protection to the pipes, for electrolytic corrosion will take place when the pipes are even a hundredth of a volt positive. His recent advice would cause great loss to any large railway company adopting it, and would be of little permanent value to any gas or water company. It possibly might help the operation of the telephone exchanges, but such help can be obtained in a less expensive and wasteful manner.

I fully agree with Mr. Edison in stating that I know of but one practical method of stopping the destruction of the pipes ; fortunately, this, at the same time, effects a large saving of power to the railway company adopting it, for, of course, the work expended in reaching, corroding and leaving the pipes is entirely lost. This is the process used by the Board of Street and Water Commissioners at Newark, N. J., U. S. A., and shown in Figure 2. The outgoing or positive current is carried to the trolley wire as before, but the negative terminal of one dynamo is disconnected from the rail return wire and joined to a wire leading to the points on the pipes which suffer the greatest amount of corrosion. The electrical pressure of this dynamo is then increased until

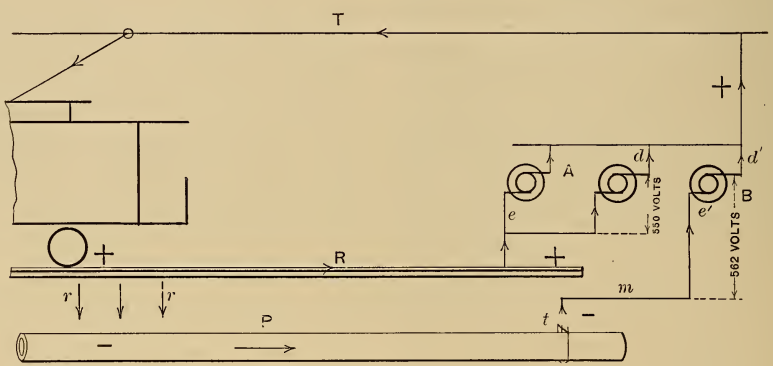


FIG. 2. DIAGRAM SHOWING HOW ELECTROLYSIS MAY BE PREVENTED.

the pipes are made two or three volts negative to the rails at the points which were previously positive and were therefore corroded. As long as the pipes are kept negative to the rails, there can be no more corrosion of the pipes and the problem is solved.

Referring more particularly to Fig. 2, *A* represents the main battery of dynamos, whose positive poles *d* are joined to the trolley wire *T*, and whose negative poles *e* are connected to the rails *R* in the ordinary manner. These dynamos are adjusted to maintain the usual 550 volts pressure between *d* and *e*. The dynamo *B* represents at first about one-quarter of the total capacity of the station ; but the proportion can be reduced when this plan has been put into service. Its positive *d'* is connected

to the trolley wire *T*, but its negative pole *e'* is connected by suitable feeder wires *m* to the points *t* on the pipes which were previously positive to the rails. The pressure of dynamo *B* is then so adjusted that it gives 5 to 12 volts more than dynamo *A*. As their positive poles are joined, this difference of pressure asserts itself by maintaining the pipes negative to the rails by 12 volts, less the previous positive charge and the loss incurred in passing the current through the feeder wire *m*.

There is no difficulty in keeping the two sets of dynamos at just the proper difference of pressure to secure this result, and the railways would be eager enough to do this if they realized that their station load could thus be reduced about twenty per cent. At the Boyd Street power house of the Consolidated Traction Company, at Newark, the chief engineer, Mr. Geo. E. Talcott, found that three hundred horse-power was saved in this way.

The method as thus far described entirely checks electrolysis of the pipes, unless it be around some poor joint on same. Such a joint can be easily detected by a low-reading voltmeter at the surface of the street, and the action stopped by continuing the wire *m*, diminished in size, to a point beyond the poor joint. It is true that, as far as described, the tendency of this method is to slightly increase the current flow on the pipes, but this is only the first step. The current reaches the pipes at *r r*, near the ends of the railroad lines, and there a difference of fifteen or more volts has often been found, the rails being positive to the pipes. This difference causes a heavy flow to the pipes, and is caused by poor bonding between the rails and by insufficient rail-feeder wires, or by the fact that the network of pipes may lead directly to the power house, while the lines of rails may take a roundabout course. But with proper bonding, the difference of pressure between rails and pipes at *r r* may be cut down to one or two volts by carrying out from the higher pressure dynamo *B* a continuation of the wire *m* to the distant rails at *r r*. Then, with the proper feeder regulators in the wires *m*, the rails at *r r* and the pipes at *t* can be kept at nearly the same potential, and the current flow on the pipes can be cut down to a minimum. However, even this scheme would not be permanent if the ordinary methods were used of making electrical connections with the pipes.

After several years of experiments at the Edison Laboratory, but one contact metal or alloy was found that, on a steel rail or an iron pipe, would prevent a film of iron rust from penetrating between the surfaces and ruining the contact. This "Plastic Alloy," as it is called, in connection with Mr. Edison's simple process of amalgamating iron or steel, forms a perfect electrical "union" of the metals instead of a mere mechanical contact; its resistance is negligible even with two thousand ampères current through a square inch of surface, and it will neither rust nor break. Several hundred of these plastic joints have been in service as rail bonds for over five years, and the rails, as far as electrical conductivity is concerned, are practically continuous, and there is no sign of corrosion.

Neither of these results can possibly be obtained with copper, since an iron and copper contact produces a serious and unavoidable thermo-electric loss, which is about six times as large as the loss due to the resistance of the metals. Thousands of these plastic joints have been used in the past year, and the electrical result is better than with welded joints. When it is remembered that a new copper bond, 5/8-inch in diameter, having the best mechanical contact, causes a loss of a half volt per joint with 1500 ampères, it is easy to realize that any large railway, by securing perfect bonding and by stopping pipe corrosion, can easily make a reduction of from twenty to forty per cent. in the power expended in operating its cars.

To apply the plastic alloy for pipe protection, a few square inches on the top of the pipe are filed clean of paint or scale and rubbed with Mr. Edison's compound, which at once turns any

iron rust into pure metallic iron and amalgamates the surface. Metallurgists have long considered impossible a stable iron amalgam, but it nevertheless exists and is so permanent that neither water nor any reagent which it will encounter under the streets can decompose it, nor rust the iron surface beneath it. A U-shaped bolt is then slipped under the pipe and a cast-iron yoke is placed over it. The end of the feeder wire *m* has been brazed to a sheet copper saddle fitted between the top of the pipe and the bottom of the yoke. The centre of the saddle on each side of the wire is cut away to form a receptacle into which, after the copper has been amalgamated, is placed the plastic alloy. The nuts are then tightened up and locked. When a joint between iron and copper is thus prepared, all the contact resistance disappears and the thermo-electric loss is much reduced. But when the alloy is used between iron or steel surfaces, both contact resistance and thermo-electric loss disappear.

Since these joints have remained underground without deterioration for over five years; since, by the above method the pipes can be maintained negative to the rails at any desired potential; and since the net result is a large saving to the railway, there seems to be no excuse for further destruction of pipes from electrolysis.

HAROLD P. BROWN.

JEREMIAH MERVIN ALLEN.

PRESIDENT OF THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

By P. H. Woodward.

TILL quite recently, young Americans, conscious of ability and eager for a career, were largely attracted to the "learned" professions. Graduates from the academy and from college, when confronted with the necessity of choosing a vocation, felt almost confined to the pulpit, the bar, medicine and teaching. Within half a century the marvelous progress of science, with the countless applications of its discoveries to practical affairs, has given a new trend to ambition, by opening fresh and illimitable fields to human effort. While the ancient highways, worn by the monotonous tread of generations, are still thronged with dusty travellers, pursuits variously combining science with business now attract with growing force keen and adventurous minds. On one line of this manifold and wonderful development the subject of this sketch has been both pioneer and creator, having built up an institution that has brought ample returns to the holders of its shares, while reaching with its beneficence every part of the United States and beyond.

From Samuel Allen, the emigrant ancestor who settled in Cambridge, Mass, in 1632, Jeremiah M. Allen was the seventh in descent, and comes of sturdy Puritan stock. General Ethan Allen was a descendant of Samuel. The family intermarried with the branch of the Adams family that gave Samuel and John to the Revolution. A taste for science and mechanics seems for a long period to have been transmitted from father to son. One was an astronomer at a time when the appearance of "Allen's New England Almanac" was welcomed as a notable event of the year. Another was one of the earliest in this country to engage in the manufacture of telescopes and microscopes. Others were contractors and builders.

Jeremiah Mervin Allen was born at Enfield, Conn., May 18, 1833. He was educated at the academy in Westfield, Mass., with the view of becoming a civil engineer. Subsequently he taught for four years, diligently improving leisure moments in reading and study. In 1865 he was made the general agent and adjuster of the Merchants' Insurance Company, of Hartford, and later he accepted a similar position in the Security Fire Insurance Company of New York city. In both places he laboured with characteristic fidelity, and with a success that attracted the attention of insurance circles. Meanwhile the life-work for which Mr. Allen had been studiously but unconsciously preparing, fell to him unsought.

In the year 1857 a number of young men in Hartford, drawn together by similarity of tastes, organized the Polytechnic Club with the view, primarily, of investigating and discussing questions of science in relation to the utilities of practical life. Among the members were Elisha K. Root, who succeeded Colonel Colt in the presidency of the armory, Francis A. Pratt, Amos W. Whitney, E. M. Reed, Professor C. B. Richards of Yale, Charles F. Howard, Joseph Blanchard, J. M. Allen and others. Although few in number, they have, on different lines of effort, made a marked impression on the events of the period. About this time Professor Tyndall threw out the suggestion incidentally in one of his lectures that the spheroidal condition of water on the fire plates of boilers might be the cause of disastrous explosions. The hint, for it was scarcely more, became the text of frequent talks regarding the cause of such explosions and the best methods of prevention. Meanwhile, Mr. Reed, on returning from a European trip, brought home the results of late experiments conducted under the direction of Sir William Fairbairn. It also became known that the Manchester Steam Users' Association had already been organized in England with the view of preventing boiler explosions by periodical inspection. Under the system as started there, the manufacturer paid a certain sum annually for the examination, receiving in return either a certificate of the safe condition of his boiler, or a report condemning it, but the certificate, like those in some places since issued by direct appointees of the State, involved no pecuniary obligation whatever, and if disaster occurred, the paper, while relieving the holder from the charge of carelessness, entitled him to no indemnity.

Although not one of the members of the Polytechnic Club was connected with insurance, the body unconsciously drew inspiration from the local predominance of the interest, which was then making Hartford famous as the home of skilled underwriters. In the course of the debates on the subject the attention of the young men was attracted to the feasibility of combining a guaranty with the inspection, thus giving both parties to the contract a pecuniary interest in the safety of the boiler. So far as known, the conception had not at that time materialized elsewhere. Although distinctly evolved in the club, the seminal idea waited several years for further development on account of the intervention of the civil war.

With the return of peace, the subject was revived, and in May, 1866, prominent manufacturers in and out of the State of Connecticut secured a charter, empowering the company formed under it "to inspect steam boilers and insure the owners against loss or damage arising from boiler explosions." In the following November the company was organized, when J. M. Allen, who had given much study to this and related subjects, was urged to take the management, but, having made other engagements for the year, was compelled to decline. E. C. Roberts was accordingly elected president, and H. H. Hayden, secretary. In October, 1867, Mr. Allen succeeded to the presidency, and under his care an experiment, seriously threatened more than once with early death, has grown into present usefulness, strength and influence.

For a long time the process was slow and the way wearisome. Most seemed to regard the new departure as a use-

less novelty that must soon run its short-lived course. What will Hartford people undertake to insure next? was a question often asked in tones of undisguised derision. In the hands of a manager less firm in conviction or less conciliatory in manner, the prophecy of disaster must have wrought its own fulfillment. Mr. Allen met the flavour of sarcasm with the antidote of pleasantry, and toiled on to create a demand which it should be his future business to supply. For the first five years the company occupied a single room sixteen or eighteen feet square, and for the same period the floor of the vault was spread with papers for the protection of the books, from the unwillingness of the officers to go to the extravagance of fitting it up with shelves. In a moment of self-indulgence the president did invest fourteen dollars in a desk for his own use, but such outbreaks of luxury seldom occurred.

Before the establishment of the company, the destruction of life, limb and property through the ignorance of boiler-makers and the incompetence of "engineers," filled a wide space in the daily record of casualties. To reduce and ultimately eliminate the hazards arising from the use of steam has been the constant aim of the management. By frequent and thorough inspections, defects are detected in their incipiency and the proper remedies applied. Structures so worn or faulty as to approach the danger line are peremptorily condemned. No chances are taken, no compromises with peril allowed. As a result, the explosions of boilers under care of the company now scarcely reach one in ten thousand per annum. Viewed as a work of beneficence, few attempts in the line of philanthropy have been equally fruitful. The heavy drain on the premiums charged to the insured comes not from payment of losses, but from cost of inspections. About two hundred experts are constantly employed in making examinations. From the outset, Mr. Allen introduced rigidly scientific methods in collecting and classifying facts. So far have his inquiries been pushed that he has prepared many formulæ that set forth with mathematical precision the strength of materials under a great variety of arrangement and conditions. Although invaluable to the company, these do not appear in its list of assets.

In 1867, Mr. Allen began the publication of the *Locomotive*, an illustrated monthly, intended primarily to explain in detail the causes and character of specific boiler explosions, but afterwards so enlarged in scope that it has long been an exponent of the most advanced studies respecting the steam boiler and cognate subjects. Mr. Allen has furnished plans for many of the most extensive steam plants in the country. As the designs aim, by strictly scientific methods, to secure the highest degree of economy, efficiency and safety, the saving in operation as compared with the superseded systems has often sufficed, in a few years, to offset the first cost of the outfit. The company has a laboratory for the analysis of waters, and for such as are injurious to boilers the proper chemical remedies are prescribed. Toward makers it holds an attitude of entire impartiality, permitting no officer or employee to have any pecuniary interest in any appliance connected with the trade.

For September 16, 1892, the twenty-fifth anniversary of Mr. Allen's election to the presidency, his associates in conducting the business in all parts of the United States arranged a surprise as touching to the principal person in the drama as it was unexpected. Being absent from the city he was summoned back by telegraph, and returned under the apprehension that unpleasant news awaited him. Hurrying from the station to his residence he was relieved to meet the welcome of a throng of familiar and beaming faces. Theodore H. Babcock, manager of the New York department of the company, speaking for all, said that the "silver anniversary" was regarded by officers, clerks, agents and inspectors of all degrees, as an appropriate time to show the universal esteem in which he was held by them. He was then taken into the next room to see the material forms in

which good-will and affection had found embodiment. There reposed a solid silver tea service, salver and complete sets of dinner, dessert and tea cutlery, and spoons of silver. In all there were one hundred and one pieces of exquisite workmanship. A plate on the large mahogany case containing most of the treasures, bears this inscription:

1867 1892

Presented to J. M. Allen
By Officers, Agents, Inspectors and
Employees of the
Hartford Steam Boiler Inspection
and Insurance Company.

Besides the silver there was an elegant album containing the photographs of about fifty persons connected with the company, and autograph letters of congratulation in verse and prose.

In 1888 the Hartford Board of Trade was organized. At the earnest solicitation of the directors, Mr. Allen took the presidency and has held it continuously since. Mr. Allen's services have been widely sought in the management of corporations and trusts, and though often obliged from pressure of other duties to decline, he is prominently identified with a number of important institutions. He is non-resident lecturer of Sibley College and Cornell University, and a member of several scientific, literary and historical societies.

With little time or taste for the scrambles of politics, Mr. Allen has rarely accepted municipal office, and then only to promote some matter of public welfare in which he took deep interest. It would be tedious to enumerate his particular services. A person of capability and public spirit is always heavily loaded with cares. Perhaps the gift most impressive to intimate associates is his readiness in overcoming physical obstructions and annoyances by the application of principles of science.

Current Topics.

THE simplicity, sometimes, of really great ideas is most excellently illustrated in the following tale which appeared a short time ago in one of the American newspapers. It is reprinted here, without assumption of responsibility for it, as of possible interest to those engineers whose years of study of refrigeration and ice-making processes have developed machinery, cumbersome at the best when compared with the simple outfit mentioned. Says the paper in question:—"A remarkably successful plan for obtaining artificial ice has been invented by an ingenious farmer of El Paso, Tex. Even in the hottest summer day this son of the soil will partly fill a tin can with water, attach it to the tail of an enormous kite and send it to the great height of three miles, where, in the rarefied atmosphere, it is promptly frozen. After a sufficient interval for this purpose, the kite is rapidly hauled in with a windlass and the cake of ice removed from the can. But the inventor is now perfecting an even more effective plan for manufacturing on a large scale. He sends up a huge kite, 150 feet long, by a steel wire cable. Under the kite is suspended a pulley over which runs an endless chain, bearing, at intervals, hooks by which the cans of water are hung on. As the cans of water going up just balance the cans of ice coming down, but little power is needed. The cans are filled with water from a pond. As each hook passes the operator, he removes the can of ice and hangs in its stead one of water. The cable travels but three miles an hour, and as the big kite is kept at an altitude of from four to six miles, the cans remain in the cold strata of the air quite long enough for the water to become solidified." Evidently the death knell of expensive ice-making machinery has been sounded.

THE several kinds of automatic fire sprinklers, now in use in many large establishments, afford familiar examples of self-extinguishment of fires. There is, however, nothing unexpected about their action; they are designed specially to put out fires, and when the sprinkler heads of fusible metal let go, and the flames underneath are deluged with water, we have simply the legitimate outcome of what was figured upon when the sprinkler system was put in. But there are a number of instances on record where the means of fire extinguishment were wholly unlooked for

and of purely accidental character. One of these was furnished several years ago in a large church where a fire, caused by spontaneous ignition in a store-room, melted the lead water pipes, and the water issuing from them quenched the flames. A similar instance happened in a tinsmith's shop. Some sheet metal pails which had been made there, were returned by the purchasers with the complaint that they were not tight. The maker resoldered them, and, in order to test his work, filled them with water and hung them upon hooks screwed into the shop ceiling. During the noon hour, a fire heated the upper part of the room so that the handle fastenings became unsoldered, and the dropping of the pails of water put out the fire. Again, in the engine room of a certain factory some oily cotton waste, left on top of a steam pump, set fire to the wooden lagging around the steam cylinders and a part of the steam-supply pipe, where it melted the soldered attachment of an automatic oiling device. The steam from this pipe escaped through the small tubes formerly leading to the oiling apparatus, and speedily extinguished the flames.

THERE have also been numerous instances of fires which died out for want of sufficient air. During the Civil War in the United States repeated attempts were made to burn New York City, and fires were at one time started in several hotels. In order to prevent premature detection, however, the culprits closed the rooms so tightly that the fires were smothered. At a hotel in another city steam pipes caused a fire in the spaces within the walls, and this, too, went out for want of enough air to support combustion. The fact that there had been a fire was unknown until some time afterward, when alterations were made in the building and the charred beams and lathing were exposed to view. Several years ago an attempt was made to destroy a block of new dwellings before the buildings were entirely finished. Some people noticing smoke issuing, rushed in to save portable things, but noticed that the fires did not appear to gain any headway. When the smoke had died entirely away, it was found that the incendiary had placed lighted candles in sawdust and other inflammable material in closets and drawers, but with such poor facilities for air admission that combustion could not be supported and the fires were eventually smothered.

AMONG the most interesting water power installations now in existence are, without a question, the artesian well plants which, of late, have gone into operation at different places in the western part of the United States, and of which an interesting account is given in the opening article in this number. Incidentally they have given prominence to the much neglected water motor, which, for years past, has led a modest kind of existence, notwithstanding its very fair claims to consideration. As a matter of fact, it has many decided advantages as a means for supplying small power, and even for comparatively large quantities some of its various modifications have been found to give very good accounts of themselves. Practically, a water motor is as easily managed almost as a water faucet. Its cost for repairs is nominal, and its first cost is exceedingly small. With this in its favour, a pretty heavy bill for water power can be afforded, and yet a considerable profit be left over steam or compressed air.

NOW that the great Niagara power plant is, in part, completed and about to realize what, for years, has been the dream of engineering economists, it is interesting to recall one of several of the pet schemes advanced in earlier days as means of utilizing the power of the Falls. The modest proposition was made by an inventor who had cropped up somewhere, to have a large tube laid from Chicago to New York City, via Niagara Falls, and then, by turning the Niagara River into a monster tur-

bine, compress air to about 250 pounds pressure per square inch in this tube. The latter was to be tapped at the cities along its line and power furnished as required. As an improvement on this scheme, some mechanical genius at the time suggested that the air compressing machinery be dispensed with as too complicated, and that the turbine be geared direct to a shaft which should be laid through the State of New York from west to east. From this shaft power could be delivered by means of belts or gears directly to the machinery in the factories along the line of the shaft. The suggestion, with all its apparent absurdity, was not more startling, however, than thousands to be found in the history of the world's mechanical progress.

A NOTEWORTHY application of gas engines has been made in England, by the River Wear Commissioners at Sunderland, where several Tangye engines have been coupled direct, without intervening belting or gearing, to centrifugal pumps for emptying a graving dock. This is probably the first installation of the kind that has yet been made anywhere, and it is all the more interesting, therefore, to be told that it has thus far proved itself very efficient and convenient. There are several pumps, each capable of discharging over 2600 tons of water per hour, and, at maximum duty, each of the engines indicates about 120 horse-power. A self-starting attachment is connected with them.

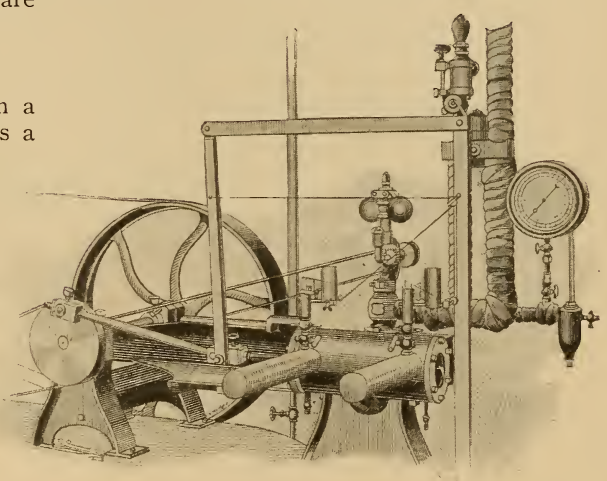
ANOTHER pumping plant, also somewhat unusual in character, is that which, of late, has been held under advisement in connection with the proposed extension of the municipal water supply of the city of Chicago. In this case, however, electricity is being looked to as the motive power. Chicago's water supply system is peculiar in that it comprises a number of pumping stations located, with one exception, along the shore of Lake Michigan from which the water is drawn through tunnel intakes, extended some distance out into the lake. Each of these stations is obliged to force the water for long distances and over great areas. With the further, exceedingly rapid expansion of the city, therefore, there has been a growing inadequacy in the quantity of water delivered for consumption, so that it has been decided as quite imperative that sub-stations be established for helping out the existing pumping capacity, and enabling the present plants to meet the city's requirements. It is for the driving of the pumps of these sub-stations that electric motors have been held in view. The minor pumps are expected to reinforce the main pumps by creating a suction from the direction of the main pumping stations and exerting pressure in the other and opposite direction. The principle would be the same as that applied in the relay stations on oil pipe lines or long mains for the conveyance of natural gas, the theory being that the diminished water pressure in outlying sections of the city is not due so much to inadequate main pumps as to the friction of the water in the pipes when conveyed a long distance and through many bends. The limit of pressure at the pumping stations is the strength of the pipe forming the mains, and this limit has already been reached; hence the desirability of relay pumping stations in outlying sections. The problem is altogether a very interesting one, and the outcome of the proposed scheme will be worth noting by municipal authorities everywhere.

To propel balloons and the various forms of air ships, so-called, by some kind of screw propeller, much after the manner followed in current steamship practice, has, for a long time, been one of the aims of æronautic enthusiasts. To equip an ordinary ship, however, in its legitimate element, with air propellers, or, in other words, with propellers revolving in the air instead of in the water, and to effect propulsion solely by their aid, is one of the latest suggestions of the times. It has been

proposed to make these air propellers similar in shape to the ordinary water screw, with sails or blades of thin sheet metal, and it is said to have been found, experimentally, that for equal numbers of revolutions, equal intensity of thrust, engine power and speed, the area of the propeller should be about twelve times that of the water screw. A big Atlantic liner, skimming over the sea with what would look like a string of mammoth, children's pin wheels on each side, spinning round in the air, is the startling vision for which, apparently, we are called upon to prepare ourselves.

To just what degree clearance in a steam engine affects its economy is a subject about which much has been said and written in the past without, after all, having brought to light anything of any particular value. More recently, however, experiments have been carried out at one of the technical schools, which have very clearly demonstrated the influence of various clearance percentages on the water consumption. The tests were made with a 4½ by 9-inch throttling slide-valve engine at the Iowa Agricultural College, and the results were given, in detail, by Professor G. W. Bissell, in a paper presented not long ago before the American Society of Mechanical Engineers. The varying amounts of clearance were obtained by retapping the indicator holes in the cylinder of the engine for one-inch pipe, and inserting in them pieces of pipe of the lengths necessary to give the required degrees of increase, the character of the construction being shown in the annexed sketch. The clearance pipes were lagged with hair-felt. Five series of tests were made,—one for each of five clearance magnitudes, and each series consisted of five economy tests, the load being maintained constant for each test, but being varied throughout the series. The original clearance of the engine was about 8¼ per cent., and this was varied up to nearly 20 per cent. in four successive stages, with the result, boiled down from a detailed exhibition covering over forty pages of tabulated statements and diagrams, that the maximum economy at all loads was obtained with a clearance of about 14½ per cent.

An account of a rather unusual gas engine trouble, recently given in a German paper, is worth noting and is quite suggestive in its way. It appears that



AN EXPERIMENTAL ENGINE WITH VARYING CLEARANCE

in a Munich establishment, where two gas engines furnished the power, premature explosions of the working charges in the cylinders became so frequent and troublesome that the engines were dismantled and thoroughly overhauled to determine, if possible, where the seat of the difficulty lay. The engines had been in regular operation for about a year and until near the end of that period had given entire satisfaction. The examination disclosed the interesting fact that the water pipes leading to and from the water jackets around the cylinders and the jacket spaces themselves were almost completely choked up with what appeared to be a species of boiler scale, which made circulation of the cooling water impossible and led to overheating of the cylinders, exhaust

valves and other working parts and the consequent irregular function. The scale, of course, was simply lime salt deposit from the heated cooling water. As, however, the water flowing through the jackets never reached, while circulating, a temperature at which salts in solution would be precipitated, it was obvious that the precipitation had occurred during the short periods after the engines stopped working. At this time the circulation of the water through the jackets ceased and, consequently, the water left in them was raised by the heat of the surrounding parts of the engines to a temperature at which precipitation of the salts held in solution became possible. A simple cure for a difficulty of this kind would obviously have been to keep the water circulating through the jackets for a short time after the engines stopped running, so as to prevent any considerable rise in the temperature of the water. Users of gas engines may find this worth bearing in mind.

An item which has recently been going the rounds, tells of an interesting steamer which, by this time, has probably been put into commission in Denmark, on two lakes in the vicinity of Copenhagen. The peculiar feature of the vessel is that in its regular work it has to make a short cross country journey, the two lakes being divided by a strip of land. Across this a railway has been constructed, crossing a highroad, which necessitates a gradient on both sides of 1:50, the metals being ordinary rails, At the two ends the rails have been carried into and under the water on a wooden structure. By means of piles the steamer is guided on to the rails, which correspond in position with two wheels fixed on each side of the steamer. The latter goes on to the rails at full speed, and travels up them on the one side and down the incline on the other, into the water, where the propeller again takes up its function. In addition to the usual propeller shaft there is another shaft, which, by means of a chain, works the small wheels on which the steamer crosses the rails. The boat also has a powerful brake to control the speed on the down-grade. It is 44 ft. long, capable of holding seventy passengers, and the engine indicates 27 horse-power. All the trials are said to have passed off in a perfectly satisfactory manner.

SOME INDUSTRIAL SUBJECTS ILLUSTRATED.

AIR AS AN INDUSTRIAL FACTOR.

CONSIDERED from a humanitarian standpoint, no representative engineer or architect of to-day will underestimate the value of pure air for ventilating and heating purposes, or fail to provide suitable flues for its introduction and eduction for schools, theatres, churches, halls of audience, legislative buildings and the like, and large manufactories with their hundreds of operatives. It is, however, doubtful if the importance which air plays in industrial pursuits has ever been calculated.

New and extensive fields for the use of air, as furnished by fan blowers, either cold, or first tempered, or heated, by steam coils or other heating agencies, as the situation may require, are frequently developing. Improving the product of the industry or lessening cost of output are the usual avenues through which these uses open up. Special study of the problems incident thereto, with detailed experiments, must then be carried on until an economical and reliable basis for calculating the proper sizes of apparatus are established. These tests have entailed the manufacture of a number of delicate and special instruments and devices for making air tests under a variety of atmospheric conditions and temperatures. The engravings appearing in connection with this article have been prepared from sketches

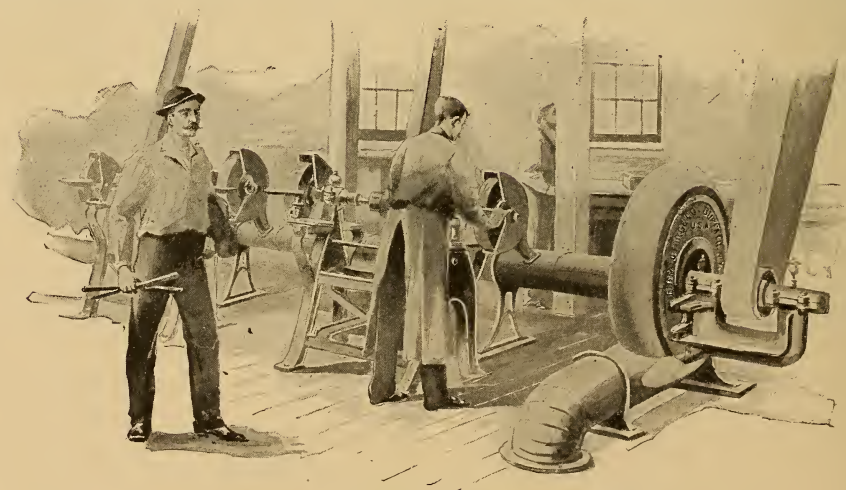


FIG. I. AIR SUCTION REMOVING EMERY GRINDINGS.

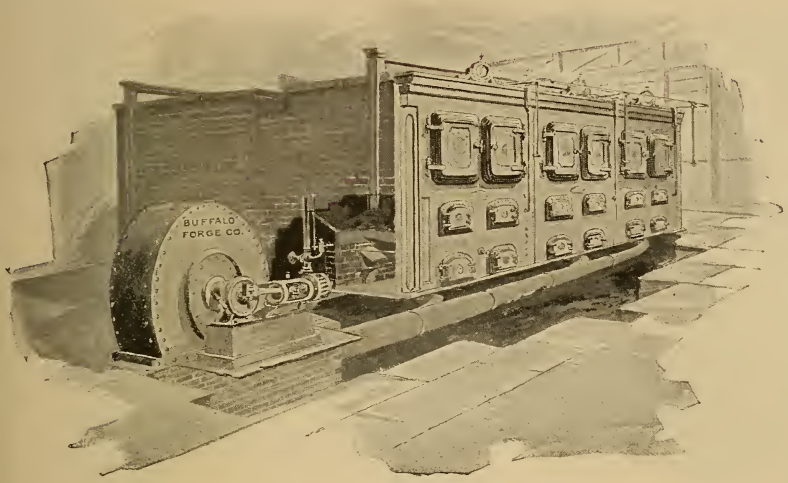


FIG. 2. FORCED AIR DRAUGHT UNDER BOILER GRATES.

taken at random, and some mechanical features are not as correctly portrayed by the artist as though they had been made from original photographs. Since the recent attitude of the various State legislatures has been so forcibly directed toward the abatement of existing nuisances in factories, easily accomplished by the introduction of fans and the improving of the atmosphere in all cases where rendered foul by the incident processes of manufacture, we observe a great many fans used for accomplishing these results, heretofore found only in the larger and more complete mills whose owners did not want to be compelled by law to introduce them, but who appreciate the possibility of their obtaining more work from their operatives by rendering the working apartments habitable.

In the first illustration, we have what is known as a "B" Volume Exhauster, handling the refuse from a series of emery wheels. There are two types of fans used for this class of work,—steel plate exhausters, specially built and extra heavy, and also cast iron fans as shown, the latter being more durable. The former style of fans are built in larger diameters and capacities, and, therefore, are more readily adapted to large plants.

The operation of an emery exhaust outfit is exceedingly simple and readily understood. The construction of the fans is such as to handle a comparatively large volume of air at a strong pressure, and the rush of the air toward the exhauster carries with it the emery grindings. From the fan the grindings are ordinarily deposited in a vat of water, or, by the use of a properly constructed separator in a closed bin or room. Blast gates are usually employed at each branch pipe, and by closing these when that

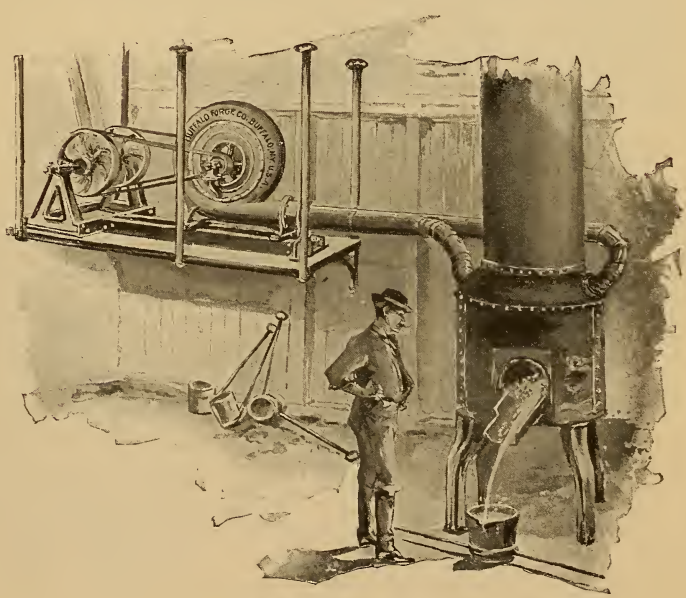


FIG. 3. WHERE A STRONG AIR BLAST IS INDISPENSABLE.

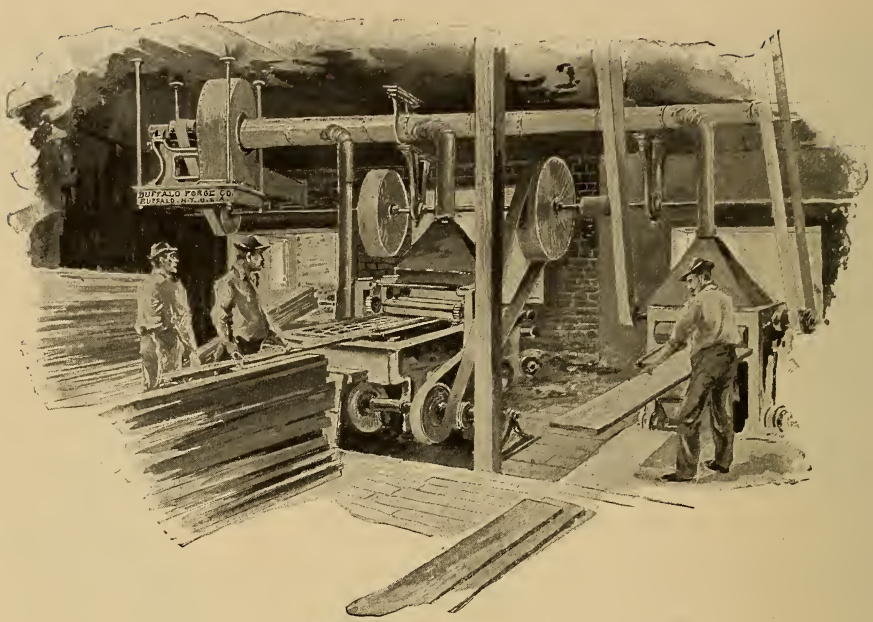


FIG. 4. AIR CARRIES WOOD REFUSE TO THE BOILER FIRES

particular wheel is not running, a saving in power is effected in proportion to the number closed off, and the consequent reduction of the amount of air allowed to pass through the exhauster.

Foundry tumbling barrels in many States are now required by the factory inspectors to be connected to an exhauster, the kinds above mentioned being suitable. With a barrel of proper construction, many of those now on the market being very convenient and efficient, the working conditions of employes are no longer what they used to be. We have now an atmosphere comparatively free from dust and other impurities. The "B" volume fan blast wheels may also be constructed of copper or other special non-destructive metals for handling fumes from acid baths, the shells having an interior lining of the same material.

The second engraving illustrates what is perhaps the most important use made of air as furnished by blowers in recent years. The largest and most complete boiler plants are now erected with short chimneys at great reduction of first cost, tall ones being rendered entirely unnecessary to obtain sufficient combustion of fuel, because fans are applied either to force air under the boiler grates or in connection with fuel economizer plants to create an induced draught. By forcing the air under the grates, it is possible to obtain perfect combustion of cheap grades of fuel, such as hard coal screening and soft coal slack. Mixed in the percentage

FIG. 5. PROGRESSIVE SMITHS DON'T USE BELLOWS.

of 25 of the latter with 75 of the former, the best fire is obtained. The usual arrangement is to equip the fan with a direct-connected engine, its speed being controlled automatically by a regulating valve acted upon direct by the steam pressure in the boiler, the rise of pressure reducing the speed of the fan, and *vice versa*. The valve is, of course, adjusted to the steam pressure which it is desired to maintain in the boilers. The air is delivered under the grates into a closed ash-pit, being introduced at the bridge wall. The idea of burning this class of fuel was first originated at Buffalo, it being a great shipping centre for mine operators, with the consequent accumulation of fine coal dust screening, etc. Precisely the same apparatus has been successfully tried in the coal regions, with the result of finding that the millions of tons of culm now piled up in these sections can be readily consumed with results practically equal to mine run coal.

Not many years ago, it was generally accepted by foundrymen that nothing short of a positive blast blower could ever fill the requirements of melting iron in foundry cupolas. To-day, few are purchased for such service. The third engraving illustrates the most efficient and economical arrangement in power and durability. It is now an established fact that the proper amount of air at an ordinary pressure affords far better results in foundry work than an insufficient supply at a high pressure, the latter being the usual result where positive blast blowers are used, the former with the fan type of cupola blower.

Few planing mill operators now follow the old time practice of removing the refuse by hand, but instead use air as a conveyor to the boiler fires through piping systems and dust separators with furnace feeds attached. Another and more important use for air in wood-working industries is its application for seasoning timber. Rapid and efficient work calls for a contin-

"THE AIR BREATHES UPON US HERE MOST SWEETLY."—*Tempest.*

ual and frequent change of air in drying apartments, at a comparatively high temperature, with the humidity under perfect control. This result is obtained by the combination of a steel plate fan and steam hot blast heater, with an air change capacity in the drying apartments approximately two or three times per minute, and of heater capacity sufficient to maintain a temperature of from 120° to 180°. The humidity is principally regulated by the introduction of a steam jet into the main air duct between the fan and the dryer.

The space at command prohibits not only a brief description but even a complete enumeration of all the uses of air as an industrial factor in the present state of progress. A few of the more common ones are the removal of odors from oil and grease, sanitary arrangements, steam drying cylinders, dye houses, bleachers, glue pots, lacquer and pickling rooms, rag warehouses, removal of steam from paper mills, and abating dust, etc., in multitude of particular processes for bringing forth the various manufacturers' products.

The heating and ventilating system to-day first considered for important public or manufacturing buildings of any size is the one in which air is the prime feature, viz., the fan system. Embodied in it are the vital elements of the ideal outfit, perfect control of the quality, quantity, humidity and temperature of air and economy of operation. For legislative buildings, schools, halls of audience, manufactories and all large structures, the system stands unique in adaptability and desirability. There is almost an endless number of ways in which the apparatus may be applied to meet existing conditions in buildings of this class. The presentation of the greatest amount of data ever published and hitherto unavailable relating to the application of fans, fan system of heating, ventilating and drying appears in the 1895 catalogue of 500 pages issued by the Buffalo Forge Company, Buffalo, N. Y. It is embellished with hundreds of handsome and expensive engravings, and the tabulated data and formulas originated by the above company places this work as a standard for basis of all computations upon the movement of air by fans for all classes of work.

THE BUFFALO FORGE COMPANY,
Buffalo, N. Y.

MODERN BUILDINGS.

"EXCELSIOR" seems to be the motto of all modern art and industry and in no department of social science has this been more apparent, in the last decade, than in architecture.

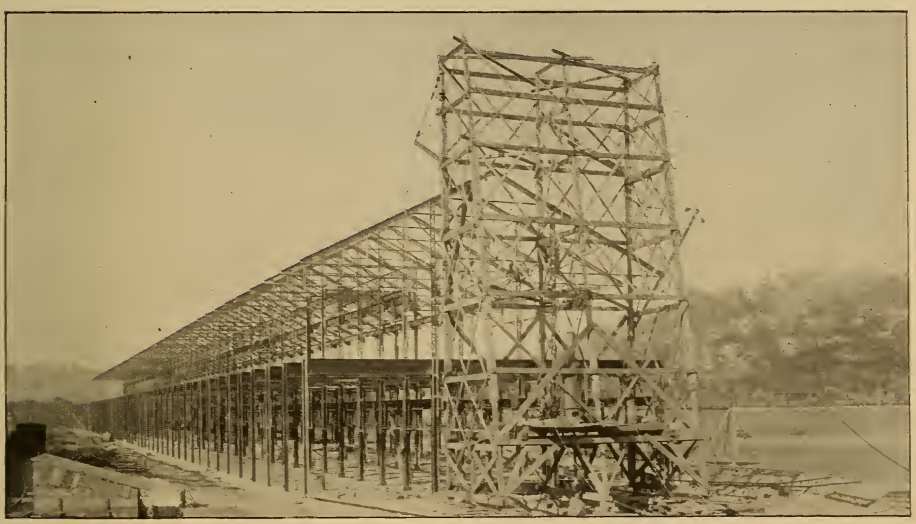
The magnificent buildings of recent construction that adorn the thoroughfares of our Metropolitan cities were not dreamed of by the architects of preceding generations, and all this is due to the advent of steel in building construction. So general has the use of steel become in the more pretentious structures, that it is now indispensable, and extends to all sorts of industrial buildings; in fact it was the industrial building that gave the impetus to open framework construction and from which the towering office building of the city has grown.

While the highest and proper aim of the architect is to be an artist, he needs the assistance of the engineer, as a builder, to determine the strength, character and fabrication of his material, especially in metallic construction where great care is required to provide for all superimposed loads, stresses of wind pressure, etc., in which the most minute details have to be considered, for in the event of the shearing of a few rivets where enough have not been provided to resist the

stresses, or the breaking of a bracket sustaining a girder, the collapse of an entire structure may be caused.

In manufacturing establishments, such as Steel Plants, Rolling Mills, Foundry and Machine shops where cranes and other machinery are constantly working, the determination of stresses and the proportioning of material to resist them, is, in this age of scientific knowledge and practical art, figured with the greatest accuracy and the proprietor of an industrial plant of to-day does not think of constructing his building without the aid of the experienced engineer.

The construction of iron bridges ante-dates the open framework of the industrial building and the engineering science required to determine the stresses



ONE OF THE NEW SHOPS OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, BRINTON, PA. ERECTED BY THE SHIFFLER BRIDGE COMPANY, PITTSBURGH, PA.

of loads on bridges, it may be said, has been the forerunner of the engineering knowledge required to properly design and construct the industrial building. Thus through the ordinary course of events it is the bridge designer who has developed into the builder of the manufacturing plant and the framework of the artistic business block. Naturally, therefore, some of the bridge building establishments have departments in their works especially adapted to this kind of construction which is now in demand everywhere from the fact that the scarcity of timber and its unadaptability to present needs precludes its use.

A magnificent example of modern steel construction in an industrial establishment, is shown by the accompanying illustration of a warehouse, 76′ 2″ wide by 754′ long, taken during the course of erection. It is one of a number of buildings of the Westinghouse Electric and Manufacturing Company at Brinton, Pa., constructed by the Shiffler Bridge Company of Pittsburgh, Pa., to whom we are indebted for this cut and information.

THE SHIFFLER BRIDGE COMPANY,
Pittsburgh, Pa.

TURN ON THE SEARCH LIGHT.

CONSCIOUS that this article is addressed to men of the highest culture in science and that the audience is a very large one, the writer hesitates to use other than the simplest language in offering to the Mechanical Engineers of America, claims or explanations for an engine, which is believed to be the very best expression of intelligent and progressive thought in the line of steam engineering that has been brought to general attention, since the day that the Corliss type of engine was designed.

During the present wonderful electric period, great strides have been made in the various phases of electrical development, the possibilities of which are so generally admitted as beyond conception, and the exacting demands for perfection in the generating power behind the dynamo are so great that it has required considerable courage on the part of engine builders to promise satisfaction. The uncertainty as to whether the faults were with the electric or steam machinery and the natural tendency on the part of the electrician and the engineer to disclaim responsibility for imperfection, has restrained the engine builder, for commercial reasons, from entering a field in which he was so uncertain of success. The time has, however, now arrived, when the electrician has so far mastered the many phases of his subject that to-day, there is no longer hesitation on the part of the general public for the installation of needed electrical machines, and the steam engine builder is forced to stand abreast with the electrician in the perfection of his product.

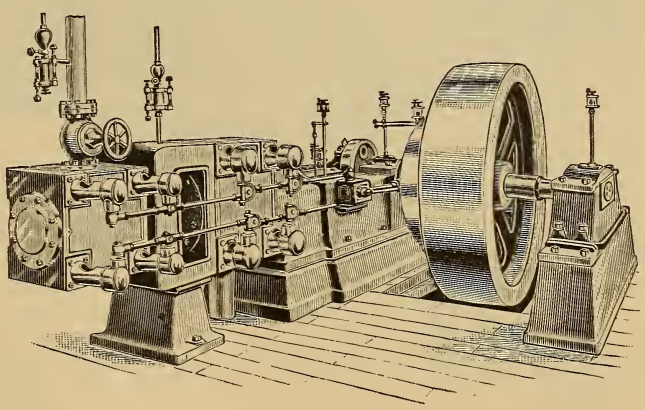
Having duly considered all this, and after many years dealing with the subject of the best use of steam, it was decided by **The Atlas Engine Works of Indianapolis, Ind.,** to undertake to meet the requirements of the day.

To tell the story that has led to the development of this high grade engine in the simplest way seems the most forceful manner of bringing the engine to the attention of those who are best prepared, by study and experience, to appreciate its merits.

It was determined to design an engine, with the end in view, of building the most perfect machine possible, without reference to what others were offering or without reference to the cost of construction. To this end, all known designs of

engines were carefully studied and investigated to discover, if possible, the most valuable features of each and every one, with the determination of improving upon everything that had already been done, if it were possible to do so.

As a result, the Atlas Cycloidal Heavy Duty Engine is presented to the world as the most conspicuous forerunner in all that relates to merit in steam engineering that is now known, and this article is written in the hope of bringing it to the attention of that class of experts, who have given so much thought along the line of better things, and who, we believe, will readily recognize the several meritorious features of the various parts that enter into the so generally successful plan.



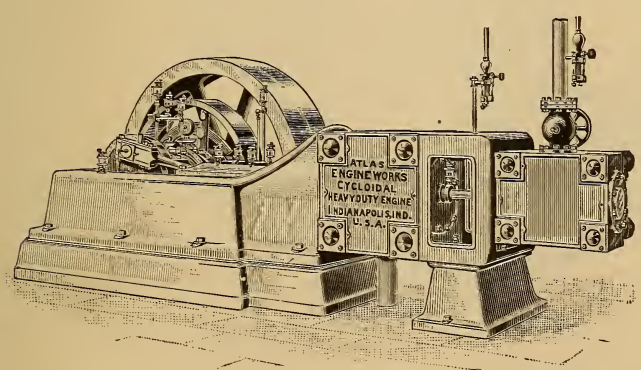
TANDEM COMPOUND ATLAS CYCLOIDAL HEAVY DUTY ENGINE, BUILT BY THE ATLAS ENGINE WORKS, INDIANAPOLIS, IND.

The minimum use of heat and water and the most uniform speed, under varying conditions, supported by the greatest strength, is what has been obtained in the design of this engine.

Accepting the four-valve system, as proven the best in principle for the quickest use and release of steam, the effort was made to simplify the valves and the valve-operating mechanism, and to substitute for the rotating, the flat multi-ported valve. Either high or moderate speed necessities are accommodated, with economical results.

Clearance is reduced to the lowest possible limit by form of valves and shortness of ports.

Finished inner faces of cylinder heads and finished piston heads reduces condensation and fixes the amount of clearance.



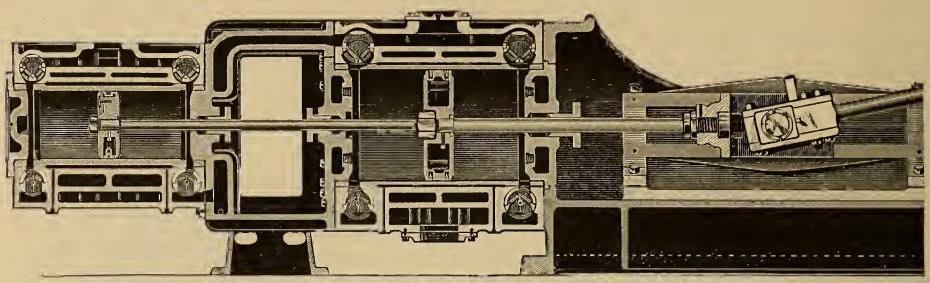
FRONT VIEW.

The ease with which admission, release and compression can be regulated is a conspicuous feature of excellence.

The direct passage from high to low pressure cylinders in double expansion, avoids loss of heat and pressure.

The full opening of the steam port is so slight a movement of a very light valve that it admits of possibilities of range in speed that is remarkable, and the lightness of the valve avoids the troublesome momentum so common in valve motion, under high speed.

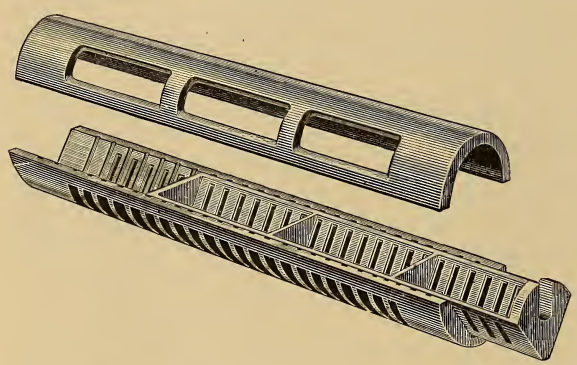
The strains are held to straight lines, without sacrifice of attractive form.



SECTIONAL VIEW OF ENGINE.

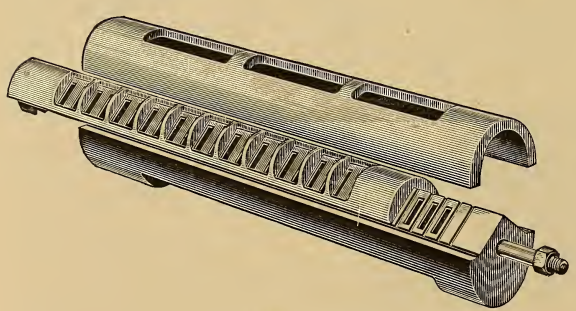
A four-valve cylinder with shortest possible ports ; live steam jacket to prevent condensation ; valve seats removable for inspection or renewal ; cylinder lining removable for repair or renewal, affords important convenience for increase or decrease of cylinder diameter to a reasonable degree.

Steam valves that are multi-ported, flat surfaced, tight-wearing, quick opening, short traveling ; operated for any port opening by the least motion of a simple cycloid ; closed by steam pressure ; without motion when under heavy pressure and removable for examination and return in three minutes time, without adjustment.



STEAM VALVE.

Positive motion multi-ported exhaust valves operated by a fixed eccentric ; maintaining uniform compression under all load variations ; removable same as the steam valves for examination or exchange for new parts.



EXHAUST VALVE.

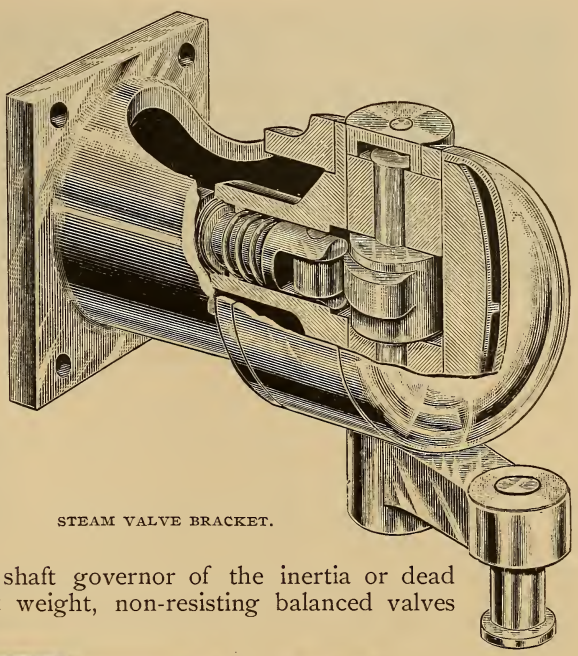
The mechanism operating the valves is stripped of all crab claws, trips and dash pots. Rods direct from the governor and two eccentrics work in lateral motion simple cycloids for the steam valves and cranks for the exhaust valves. All are made of closest steel, are free from perceptible wear, conveniently accessible for care, with but very light duty. Every part is constructed in the most particular and best manner known.

A heavy locomotive main cross head of abundant weight to take the impact of steam on the piston, equalize the pressure on the crank pin and diminish wear upon the piston and cylinder.

Direct connection between eccentrics and valve rods. Absence of objectionable rock shafts. Diminution of wear by the mounting of one slide upon the other. Only the differential motion occurs between the two ports of the valve cross head.

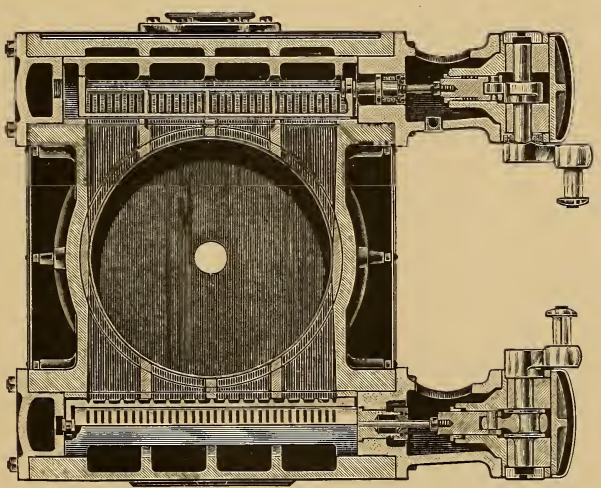
A plain heavy strap joint rod, the strap of which is the special feature. No parts strained by bending. Built up of two sides and one end piece. Tenons on the ends equal in strength to the sides take the entire strain. The through-going bolts merely hold the parts together.

A removable main bearing, whose diameter equals in inches one-half the cylinder diameter and whose length measures the same as the full diameter of the cylinder, the frictionless journal box of which can be taken out for renewal by simply jacking up the shaft and wheel.



STEAM VALVE BRACKET.

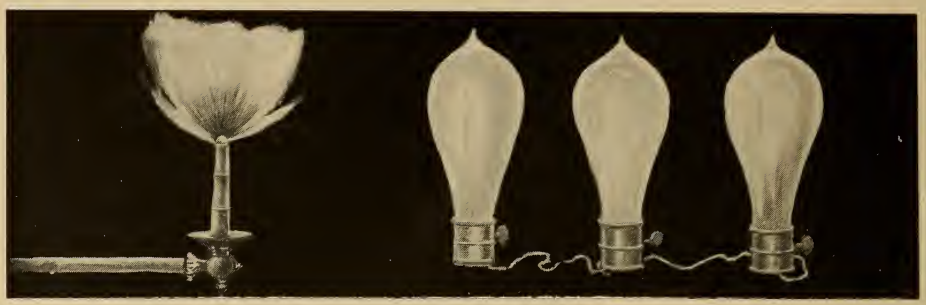
A strong roller bearing shaft governor of the inertia or dead wheel form controls the light weight, non-resisting balanced valves



CYLINDER SECTION THROUGH VALVES.

with so little effort that there is practically no variance in speed. All the joints of the governor have roller bearings. Turn on the Search Light.

THE ATLAS ENGINE CO.,
Indianapolis, Ind.



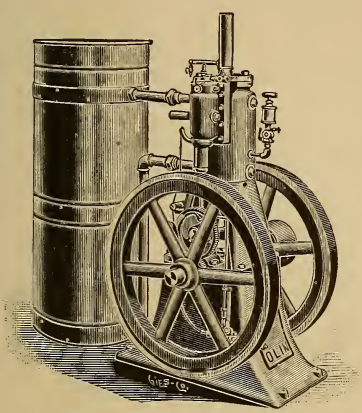
THE GAS CONSUMED IN ONE 16 C. P. GAS JET IF USED WITH A OLIN GAS ENGINE WILL PRODUCE THREE 16 C. P. ELECTRIC LIGHTS.

ECONOMICAL POWER.

OF all the machines that mark the industrial greatness of the Nineteenth Century, the engine unquestionably stands first. It is a thermometer of our progress. For in such degree as it has been made a ready and efficient servant; so has our commercial life expanded. For many years the steam engine has been the motor which has chiefly contributed to this result. But it has now reached the point where its improvement is very slow, and its practical efficiency very near the theoretical, that can be obtained. It is but comparatively recent that the gas engine has come to the front. The last fifteen years marks in it a period of remarkable growth. From a crude affair, continually getting out of order, and noisy, it has become a quiet, highly economical and reliable machine of the first order. For a gas engine to come up to the ideal standard it must be simple in design; not liable to get out of order; the parts must be accessible; it must be economical in the use of fuel; the ignition of the charge must be positive; the governing must be close; it must run quiet; and it must be durable.

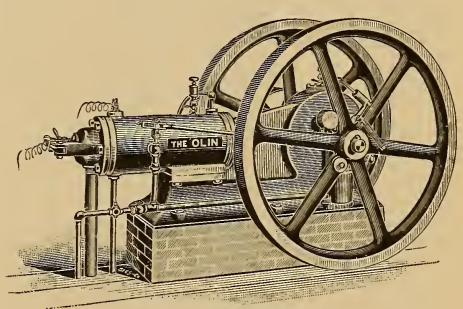
These points of excellence have been striven for by many builders and designers with varying success. But to get the foregoing combination in the highest degree, without sacrificing one good point for another, is not so easy. However, as illustrative of what has been done, and can be, attention is invited to the engines of The Olin Gas Engine Company of Buffalo, N. Y., whose agents in New York City are the Ruggles-Coles Engineering Company, 39–41 Cortlandt street. This company manufacture two general types of engines. That is, engines getting an impulse every revolution; and those getting one every second revolution; or four-cycle and two-cycle. The two-cycle are built only in sizes of 10 h. p. and over and are horizontal in style. The impulse every revolution is obtained by enclosing the crank chamber into which pure air is drawn, then slightly compressed and transferred to the working end of the cylinder; also by an independent gas-pump for pumping the gas into the working cylinder with the air just before the charge is compressed and fired. The cycle of operations is as follows: the piston on its instroke draws air into the crank-chamber; then on its out-stroke slightly compresses it; when the piston has gone three-fourths of its out-stroke the exhaust valve is opened and the exhaust relieved; then as the piston completes the out-stroke it uncovers ports admitting the slightly compressed air to sweep through the cylinder and clean out the old charge and replace it with the pure air from the crank-chamber. Then when the piston has made about one-half of its instroke a little gas valve is tapped by the governor eccentric-rod, and it admits a charge of gas into the working chamber from the independent gas pump; then the exhaust closes and the mixed

charge is compressed and fired. Thus every revolution an impulse is obtained when working at full power. This engine is characterized by great smoothness and steadiness. The design is such as to admit of a leather seat for the air-suction valve ; and the exhaust-valve is handled by rocking lever and eccentric, making it exceedingly quiet. Lubrication is so provided for that it is thorough and reliable. All friction surfaces subjected to heat are water-jacketed. Even the exhaust-valve-stem is water-jacketed and means provided for its lubrication. In this engine the compression of the charge beginning at one-half in-stroke and the exhaust opening at three-quarter out-stroke, the expansion is carried much farther than in other engines ; thus tending to greater economy and a quiet exhaust.



VERTICAL OLIN GAS ENGINE.

These engines are adapted for manufactured, natural, or producer gas. The four cycle engines built by this company are both vertical and horizontal. The vertical ones ranging from two-thirds to 8 h. p., and the horizontal ones from 10 h. p. upwards, and are adapted for any kind of gas, or gasoline direct from the tank. Their remarkable simplicity will be appreciated from the following statements : The gas engine has three simple poppett-valves and two valve-chambers, and the gasoline engines only two poppett valves and one valve-chamber. Any one of these valves can be easily removed and put back in place again in a minute's time. No fine adjustments are required in any part of the engine. The governing is accomplished by automatically controlling the exhaust-valve ; that is, holding it open when the speed is up to the normal. This method has been found to be economical as well as efficient, as it relieves the piston from doing work in compressing idle charges of air when the engine is running light. The governor is located in the gear and is sensitive enough to please the most fastidious. The work thrown upon it is very light, as its function is merely to indicate the time that the engine is to take an impulse.



HORIZONTAL OLIN GAS ENGINE.

All horizontal engines of this type are so designed that the speed may be varied, and all parts lubricated, while the engine is running. This is found desirable in large engines for many kind of manufacturing and industrial work. The effort to make this, as well as the other type of engine, silent has been crowned with success, as the action of the valves in seating is so easy, and their moving parts so cushioned and muffled that the noise is very slight.

The gasoline engines take gasoline directly from a tank (which may be at a distance from the building) by a simple pump. The vaporization of the gasoline is so perfect that the heaviest grades may be used, even low grades of kerosene have been used with success.

In the manufacture of these engines, the interchangeable system has been adopted ; standard gauges, reamers, jigs and templates being used, so that any part

from a new piston-ring to a new base can be ordered with the certainty of its being right. Especial care is given to the quality of material used. Nothing but the best is a maxim with the builders. All cranks are steel ; cylinders, pistons, rings, valve-seats, etc., are cast from a special fine grained tough iron ; phosphor-bronze, A1 babbitt, chilled iron, and hardened tool steel for such journals and wearing surfaces as experience has proven best adapted.

For isolated lighting plants the gas engine is coming into great favor, and for a number of reasons, viz.: the price of gas is practically a fixed thing for any given locality, and is not subject to the caprice and greed of electric light companies ; again it is a motor easily handled, not requiring a licensed engineer, but simply the occasional attention of a careful man or woman of fair intelligence. It is cleanly and safe as there is no fire-box with its attendant dirt and ashes, and no boiler with its steam and danger of explosion. Its economy as compared with the steam engine is very marked, as the average gas engine will convert five or six times the number of heat units in the fuel, into work that the average steam engine will do. The following problem will make clear the economy of the gas engine for electric lighting.

We will take for example an engine using 20 feet of 16 candle-power gas for each horse-power an hour. This gas would furnish four 5-foot burners giving 16 candle-power of light each—or 64 candle-power of light for one hour. Now, this same 20 feet of gas used in the gas engine gives one horse-power one hour, which horse-power will run ten 16 candle-power incandescent electric lights—or 160 candle-power of light for one hour. Thus making a clear gain of the difference between 160 and 64—or 96 candle-power of light more than the 20 feet of gas. In producing arc lights 12 times the light is obtained from the same power or gas consumption as would be obtained in producing incandescent lights. In producing electric lights with natural gas used in the engine, the economy is greater than the proportionate difference of price of the two gases, as natural gas contains more heat units to the cubic foot than the illuminating gas. These are fair estimates and show the remarkable economy of the gas engine for electric lighting. Why not use electric lights instead of gas lights?

OLIN GAS ENGINE COMPANY,
Buffalo, N. Y.

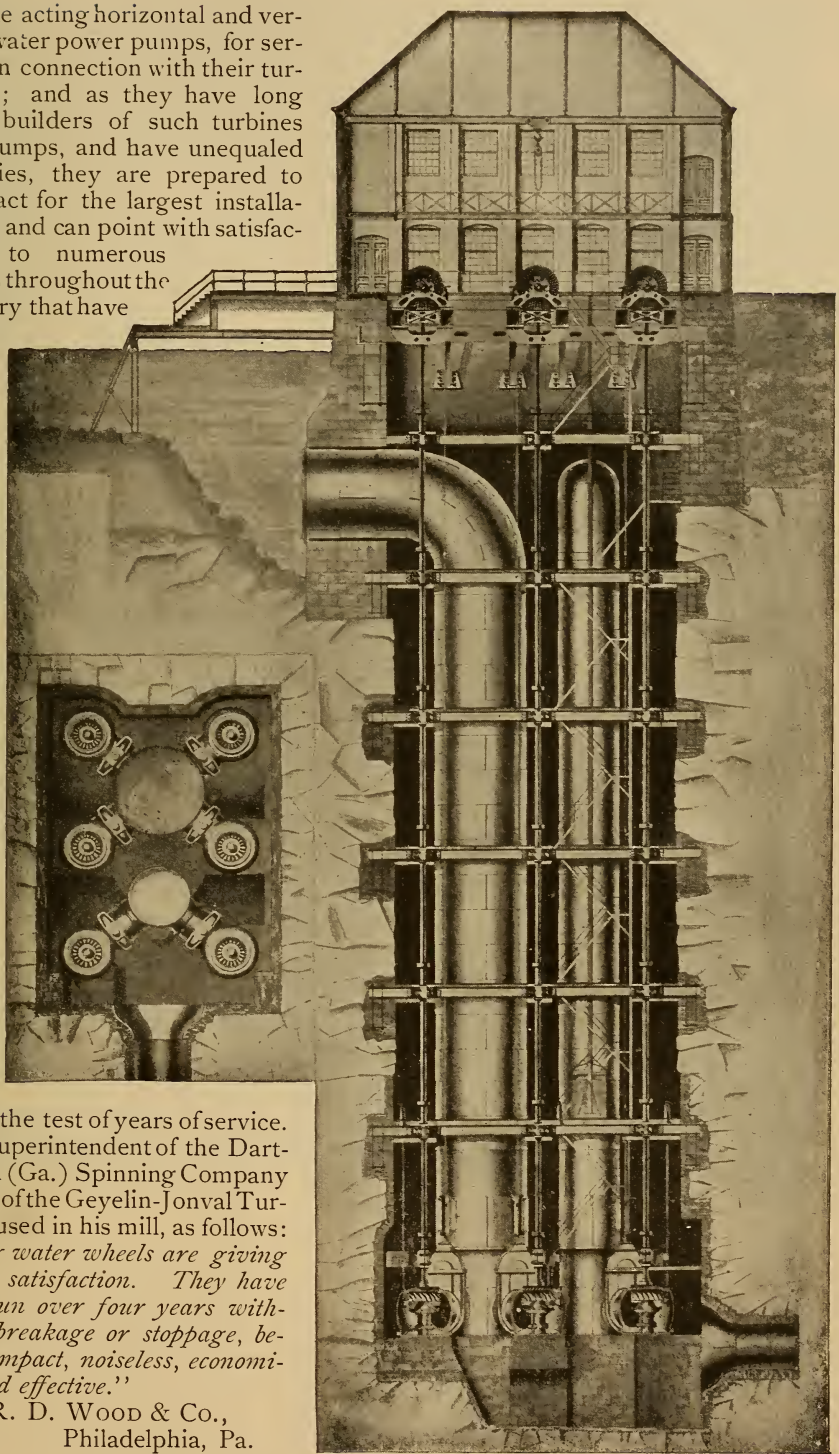
THE GEYELIN-JONVAL TURBINES.

THE accompanying cut is a general view of the now famous series of Geyelin-Jonval Inverted Turbines, each of 1100 horse-power, erected for the Niagara Falls Paper Company, Niagara Falls, N. Y., by R. D. Wood & Co., Philadelphia, which are especially notable in that they were the first to be installed and operated with the water power supplied by the Niagara Falls Power Company through their splendid canal and tunnel.

As is clearly shown, the great pressure due to the 140 feet of fall, instead of tending to decrease the efficiency of the turbines, is in part utilized through the adoption of the inverted type of wheel, to counter-balance the weight of the vertical shafts and gearing ; the installation including the iron and steel supports in which these heavy vertical shafts and gearing are carried. These turbines have now been in operation some eighteen months, giving a high percentage of efficiency, and showing a surprising degree of durability and steadiness under varying conditions of service.

The builders of the Geyelin-Jonval Turbines are prepared to offer both single and double wheels, especially adapted to meet local conditions, and for any required service. They are also prepared to build both single and

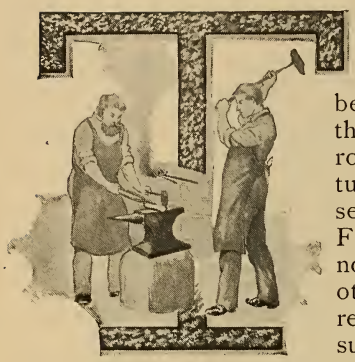
double acting horizontal and vertical water power pumps, for service in connection with their turbines; and as they have long been builders of such turbines and pumps, and have unequaled facilities, they are prepared to contract for the largest installations, and can point with satisfaction to numerous plants throughout the country that have



stood the test of years of service. The Superintendent of the Dartmouth (Ga.) Spinning Company writes of the Geyelin-Jonval Turbines used in his mill, as follows: "*Our water wheels are giving entire satisfaction. They have now run over four years without a breakage or stoppage, being compact, noiseless, economical and effective.*"

R. D. Wood & Co.,
Philadelphia, Pa.

THE CONSTRUCTION OF THE TUNNEL.



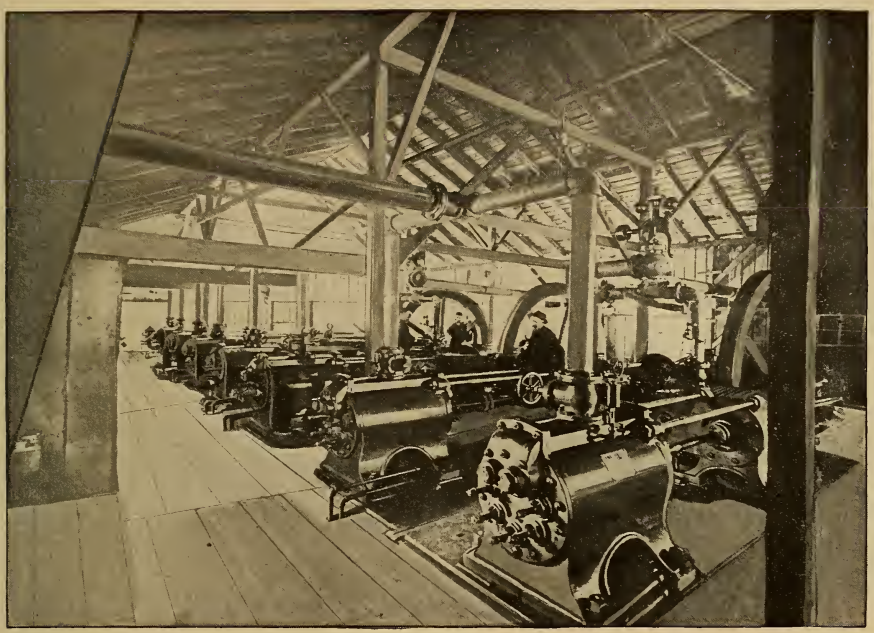
THERE is no more interesting chapter of the Niagara Falls enterprise than that relating to the construction of the tunnel. Fast tunnel driving in the United States began with the construction of the West Shore Railroad, the tunnels of that Road being about the first to employ rock drills of the modern type and almost every important tunnel made since the West Shore Road was built has seen a new record made for speed. To this the Niagara Falls tunnel is no exception, the speed made there being nothing less than phenomenal and far in advance of any other record. To complete the tunnel within the time required it was necessary to sink three shafts from the surface from which the tunnel was driven in both directions.

In tunnel driving the upper portion or "heading" is taken out first, the remainder being removed in one or more "benches." In previous work there has been much loss of time and labor due to rehandling the broken rock from the heading which was dumped over the first bench and reloaded at its bottom. In the Niagara Falls work a removable platform was

AT WORK IN THE TUNNEL.

suspended at the level of the upper bench over which the broken rock from the heading was taken and dumped into cars at its further end, the gathering of the broken rock from the bench being carried on beneath this platform. In this way a great amount of labor was saved as will be readily seen. The plan described was also of assistance in reaching the remarkable speed with which the tunnel was driven.

The first of the accompanying illustrations is from a flash light photograph of



A GROUP OF COMPRESSORS.

a tunnel heading at work. It accurately shows the methods employed and is the first authentic picture of its kind to find its way into the public print and illustrate the doings of the underground world. No picture, however, can reproduce the stirring scene which forms the reality, than which there is none more impressive in the entire field of legitimate industry. It is a hand to hand contest with nature in her stronghold. The deafening roar of the drilling machines, the shadowy forms of the workmen seen through the smoke and dust and rendered barely visible by the flickering light of the torch lamps, while over all hangs the suggestive odor of dynamite, all combine to form a scene not to be forgotten by any one who has once witnessed it.

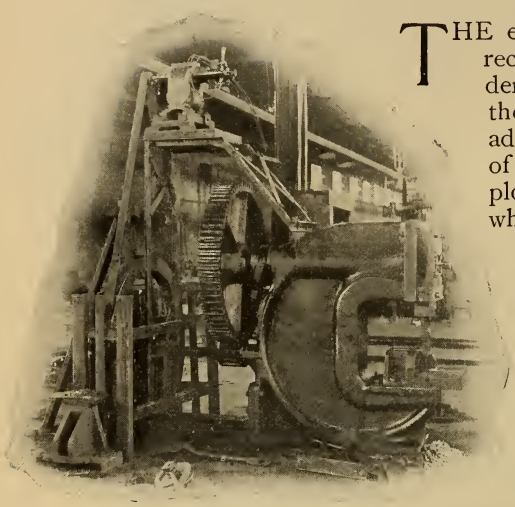
The rock drills will be seen in position mounted upon their columns, which latter are held in position by powerful jack screws. The drill holes are arranged in vertical rows, the two centre rows inclining toward one another, forming what is called the V or centre cut, this disposition of the holes being made to assist in breaking out the central portion of the rock by the dynamite blast. Outside this centre cut two rows of holes are usually placed on each side. The entire set of holes is drilled before the machines are removed, after which the holes are loaded with explosive and fired—the centre cut first, and the first and second "side rounds" following in succession.

The excavating machinery employed consisted of three 18 x 30 duplex air compressors and twenty-five Little Giant rock drills furnished by the Rand Drill Company, 23 Park place, New York. The second illustration shows the plant of compressors in position and at work, their large capacity being required by the pumping occasioned by the immense quantity of water met with.

The highest record of work for a single heading was 338 lineal feet of tunnel in 26½ days, which as before stated leads the record. Great credit is due to Messrs. Rodgers & Clement, contractors for the tunnel, which is unique among such enterprises from having been completed in less than contract time.

THE RAND DRILL COMPANY, 23 Park Place, New York.

ECONOMICAL POWER DISTRIBUTION.



THE electric distribution of power in shops is now receiving considerable attention. It has been demonstrated in many cases that this method is the most economical, as well as having many advantages over the usual method where a series of shafts, countershafts and belting are employed. Experience has taught that in shops where both large and small machinery is used it is economy to operate each large machine with a separate motor, and to group the small machinery together in sections, driving each section with a motor.

The principal saving in power realized by the electrical system of distribution is due to the fact that when a machine is stopped the power required to drive it stops at the generator and not simply at the machine itself, as is the case when driven by a system of shafting. Further, when the load is reduced the loss in line wire between generator and motor is reduced directly in proportion to the reduction of current consumed by motor. This regulation is instantaneous, and at any one time the dynamo only generates as much current as is needed by the motors at that particular time.

The attention of shop owners is invited to the following figures taken from the books of the Brown-Ketcham Iron Works Co., Indianapolis, Indiana, where Jenney electrical apparatus is in operation.

This company is engaged in the manufacture of structural iron work for buildings and bridges, and frequently handles pieces of from 20,000 to 30,000 pounds weight, the average yearly output being from eight to twelve million pounds. The principal shop is fitted with heavy machinery, very much scattered on account of the bulky character of much of the work done. Following is a partial list of machines in operation :

A heavy shear capable of cutting off a 6″ x 6″ x 1″ angle iron, operated by a seven and one-half horse-power motor directly belted to fly wheel.

A heavy plate shear similarly driven.

Six (6) punches capable of punching a 1½″ hole in ¾″ steel, each run by three horse-power motor, one of which is shown by the accompanying illustration.

A double-headed rotary planer capable of facing off the ends of a column 2′ 6″ in diameter and 34′ long.

A short shaft, operated by a ten horse-power motor, runs several lathes and shapers, seven machines in all.

A ten horse motor on a Sturtevant blower, consuming fourteen horse-power during ten hours' run (has been doing this for nearly three years).

In addition to the above is a 15,000 pound traveling crane, traversed by a three horse-power motor.

The maximum power taken by these machines was thirty-five horse-power, and the average load about twenty-five horse-power, actually shown by the electrical meters in power room. (What would it have been with the ordinary shaft and belt transmission?) This may be accounted for by the fact that all machines do not run at maximum power at same time.

In the old and smaller building, burned and replaced by the present structure,

shafting, gears, countershafts, quarter-turn belts and hangers were used, and when a machine was shifted in position a realignment of shafting often became necessary.

We have from the company that their average yearly expense for power maintenance in old plant amounted to $3000. On the other hand, with present equipment an average taken for the twenty (20) weeks ending June 30, 1894, shows a yearly cost of maintenance with the electrical system of $493.

If the present shop (much larger than its predecessor) were run by shafting, it would be necessary to use counters, hangers, pulleys and belt for each machine and to drive the whole system from a shaft 370 feet long. All of this shafting would have to be run whether the machines did or not, and the power thus expended would be a large per cent. of the total energy generated by the power plant, and this loss would be continuous throughout the entire running time.

Here, then, has been made a direct comparison between the cost of operation of a modern machine shop by the electrical and the old methods, and we find nearly a six-fold advantage in use of the former.

A recent test of power required to drive a bicycle factory developed that to drive line-shafting and counter-shafting with all machinery out of service required about twenty-five horse-power, and with average working load the total power consumed was only about thirty-five horse-power. It will be seen from the foregoing that when the ordinary belted shop is run on light capacity the percentage of loss in shafting is greatly increased. Aside from the economy there are many other advantages realized in electrical distribution.

In large shops it is often necessary to shut down, either to fix a belt, to cool a hot box or for some other cause. While the stop may only last for five or ten minutes, the loss due to a large number of men stopping work amounts to considerable. The electrical system of distribution overcomes this loss, for the stopping of one machine or section does not interfere with the balance of the works. Furthermore, irregular power due to slipping of belts is overcome, and on acccunt of the electric motor being under control, more work can be done in a given time. There are other advantages which we will not enumerate at this time.

In order to get the best results with greatest economy, it is essential that the electrical apparatus be constructed in a thorough manner to insure durability and that it should have high efficiency.

The apparatus put on the market by this company is the result of many years' experience in building electrical machinery, and we have therefore long ago passed the experimental stage.

Jenney dynamos and motors have been in use for many years all over this country and in many foreign countries.

This company builds a complete line of multipolar generators, adapted for direct connection to steam engines; also a full line of multipolar belted generators, for large sizes, and bipolar machines for smaller sizes.

The last few years special attention has been given to electric elevator service, and we are now supplying motors especially adapted for this service to several elevator companies.

Our latest type of elevator controller is a very simple device and was especially designed with a view to safety, and it is of such construction that any inexperienced operator can handle it with safety.

We are also building motors of different sizes, expressly for operating launches, and our motors were used in two very fine launches which were used on the lagoons at the World's Columbian Exposition.

We are prepared to furnish complete power equipments, street railroad or power generators and electric light plants. Correspondence solicited.

JENNEY ELECTRIC MOTOR COMPANY,
Indianapolis, Indiana, U. S. A.

THE USE OF "GIANT" PORTLAND CEMENT ON THE NIAGARA FALLS TUNNEL.

WHEN the work of putting in the heavy brick lining of the Tunnel was begun, tests were made of a number of different cements, and finally "Giant" Portland was selected on account of its superior merit.

The work to be done was considerable, there being 13,000,000 brick required, together with much massive cut stone in the Wheel-Pit and connecting tunnels, and what was absolutely necessary was a cement that combined strength and uniformity in quality.

The matter of price was a secondary consideration, as the ultimate success of the whole stupendous undertaking was dependent on the stability and soundness of the masonry lining of the Tunnel, for should this be faulty, the rushing water passing through with a velocity of 26½ feet per second would soon tear out the lining and render the Tunnel useless until repairs could be made.

The heavy brick lining was necessary on account of the rock formation being a friable shale, which crumbled badly upon exposure to the air for a few hours.

As Division Engineer in charge of Construction, it was an important part of my duties to see that all materials furnished for the work were fully up to standard, and in all about 70,000 barrels of "Giant" Portland cement were used and with the most gratifying results.

The mortar, composed of 1 part Cement and 3 parts Sand, set up finely, and after the work was completed it was necessary to cut through the brick lining to connect the small lateral Tunnel from the Niagara Falls Paper Co.'s Wheel-Pit. This Tunnel is about 7 feet in diameter, and it required four men working for two days before the opening could be cut through to the solid rock wall. The bricks of the tunnel lining were shattered and split into small fragments, and the mortar was found to be much harder and stronger than the brick, and not a whole brick was taken out.

"Giant" Portland was put to a peculiar "boiler test" on the work here. A discharged employee, for revenge, cut a hole in the side of one of the boilers used on the pumps, and it was necessary to keep these pumps at work and there was no time to put on a patch, so as a makeshift a patch of neat "Giant" Cement was plastered on the outside of the boiler, and six hours afterwards the boiler was filled and steamed up. It was found that the improvised patch was all that was required, and the boiler worked in this condition, under 110 lbs. pressure of steam, until the work was completed (about three weeks). This is a remarkable test to put any cement to, and goes to show the strength and adhering qualities possessed by "Giant" Portland Cement.

Yours very truly, WM. S. HUMBERT.

NIAGARA FALLS, N. Y., June 10, 1895.

On the next page will be found a series of Long Time Tests of Giant Portland cement on the Niagara Tunnel and other important work in America.

LESLIE & TRINKLE,
22 South 15th Street, Philadelphia.

Long-Time Tests.

Tests of over Three Hundred Thousand Barrels "Giant" Portland, on five of the largest dams in the United States; on the Niagara Falls Power-Tunnel, and the Reading Terminal Railroad and Station, in Philadelphia, for periods up to five years.

The only records of long-time tests on Portland Cement now published in the United States.

BRAND	Mode of Mixing.	1 Day		1 Week		1 Mo.		3 Mos.		6 Mos.		9 Mos.		1 Year		15 Mos.		18 Mos.		2 Years		3 Years		4 Years		5 Years		FINENESS.		
		Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Residue on No. 50 sieve, 2,500 holes to sq. in.	Residue on No. 74 sieve, 5,180 holes to sq. in.	Residue on No. 100 sieve, 10,000 holes to sq. in.
"Giant" Portland																														
Sodom and Bog Brook Dams, New York Aqueduct. About 50,000 bbls.	Neat	1,025	140	1,398	348	220	422	180	540	100	634	30	638	180	682	30	687	110	672	110	694	90	736	60	771	10	840	.....	.....	18.0
	2 to 1	....	...	220	166	120	280	140	364	84	468	50	468	90	490	36	526	100	530	100	564	130	680	120	674	20	700			
	3 to 1	....	...	226	140	140	234	112	350	110	428	30	428	240	420	40	500	80	514	80	512	160	572	...	...	10	590			
Titicus Dam, New York Aqueduct. About 100,000 bbls.	Neat	3,448	157	4,165	380	637	476	505	529	478	575	479	599	350	642	181	594	135	584	137	641	62	668	...	...	...	...	.....	.....	11.7
	2 to 1	....	...	2,934	200	424	317	281	450	321	491	278	532	219	549	157	557	92	541	52	536	37	573							
	3 to 1	....	...	1,604	115	260	185	450	289	133	347	146	311	132	426	70	424	66	416	126	419	7	483							
Carmel and Craft's Dams, New York Aqueduct. About 40,000 bbls.	Neat	1,786	140	1,075	343	324	443	551	517	529	548	491	568	289	617	...	...	273	601	211	611	...	...	...	...	...	...	.....	.....	14.7
	2 to 1	....	...	1,642	182	216	308	85	445	87	480	76	472	43	585	...	...	49	477	55	475									
	2 to 1 from Mortar Box	....	...	61	164	51	237	8	385	11	494	8	491	7	367	...	...	12	516	3	568									
	3 to 1	....	...	13	100	13	174	7	319	12	372	11	398	10	413	...	...	8	401	10	406									
	3 to 1 from Mortar Box	....	...	45	112	31	166	6	310	8	480	7	500	9	541	...	...	7	437	5	406									
Reading Terminal Railroad and Station, Philadelphia. About 60,000 bbls.	Neat	....	...	329	315	267	376	69	451	15	549	16	576	10	523	1	640	...	...	...	...	...	...	...	...	...	...	.090	10.04	14.79
	3 to 1	....	...	536	79	431	129	104	174	20	228	15	225	47	261	5	287													
	2 to 1 from Mortar Box	....	...	190	84	180	144	17	219	13	234	25	281	62	325	12	417													
Niagara Falls Tunnel, Niagara Power Co. 60,000 bbls.	Neat	....	...	495	321	309	420	12	514	24	562	...	...	24	661	...	...	...	...	...	...	...	...	...	...	...	...	.....	.....	14.9
	2 to 1	....	...	482	152	271	242	54	369	20	454	...	...	7	472															
	3 to 1	....	...	527	98	399	177	143	254	181	301	...	...	12	391															

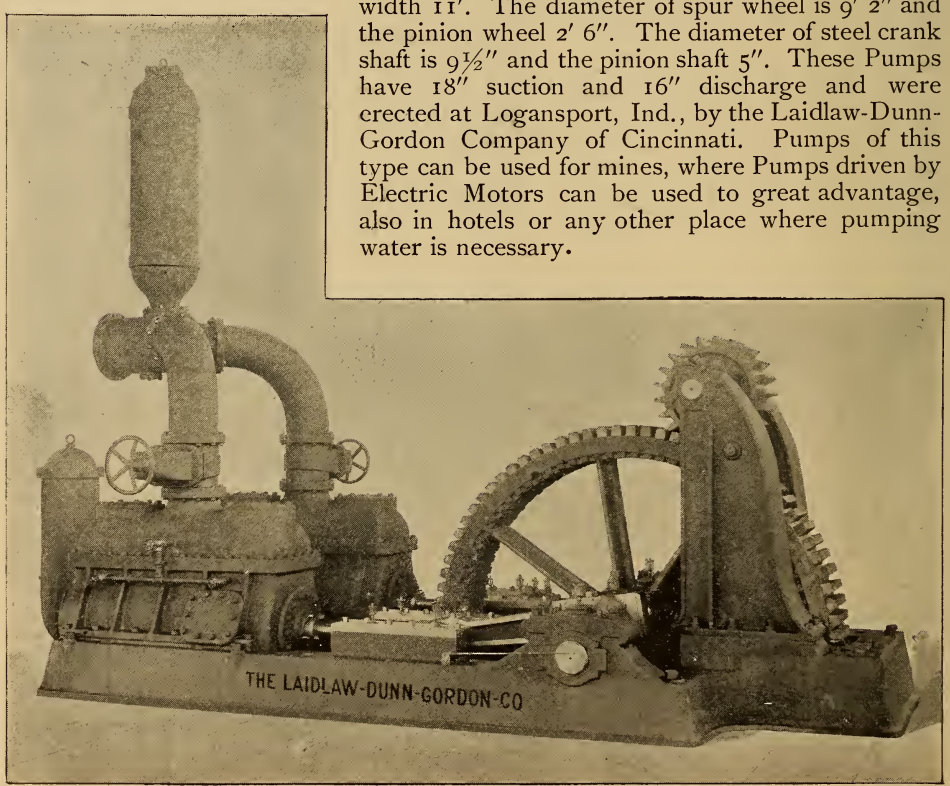
ELECTRIC MOTORS APPLIED TO PUMPING MACHINERY.

By Robert Laidlaw.

THE vast improvements made in the last few years in Electric Motors, has increased the many uses to which Electric Power can be applied. Among the more recent is the application to driving Power Pumps for water-works for the supply of towns and villages.

It has been found that where a Water-Works Plant and an Electric Lighting Plant can be operated from the same boilers and in the same building, there is much greater economy, and especially so, if the plant can be located on the line of a railroad where fuel can be procured without the expense of hauling ; but the trouble is, a good water supply cannot always be obtained on or near the railroad, and it being necessary to place the Pumping Machinery in close proximity to where a good water supply can be secured, and that sometimes a long distance from a railroad and often from the village, makes it very expensive and inaccessible. Here is where the economy comes in by putting in a Power Pumping Plant operated by an Electric Motor. The generators can be placed at the lighting plant and the current carried to the motor at the pumping plant. The Pumps can be driven direct from Motor by worm gear, or by belt from the motor to pulley on pinion shaft of Pump.

The accompanying engraving shows a Duplex Power Pump of 3,000,000 gallons capacity in 24 hours. The plungers are 18″ diameter by 18″ stroke, and the Pumps are designed for a safe working pressure of 125lb per square inch. The pinion on this particular Pumping Engine is placed on top of the spur wheel, so as to be near the floor level, as the Pumps are placed in a pit about 5′ deep to get them closer to the water supply. The length of Pumps over all is 19′ and the width 11′. The diameter of spur wheel is 9′ 2″ and the pinion wheel 2′ 6″. The diameter of steel crank shaft is 9½″ and the pinion shaft 5″. These Pumps have 18″ suction and 16″ discharge and were erected at Logansport, Ind., by the Laidlaw-Dunn-Gordon Company of Cincinnati. Pumps of this type can be used for mines, where Pumps driven by Electric Motors can be used to great advantage, also in hotels or any other place where pumping water is necessary.



DUPLEX POWER PUMP MANUFACTURED BY THE LAIDLAW-DUNN-GORDON CO., CINCINNATI, OHIO.

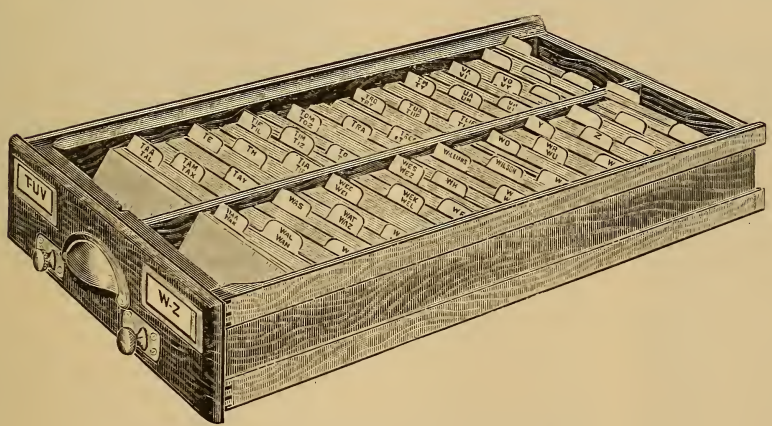
LABOR SAVING DEVICES.

THE Globe Company, of Cincinnati and New York, have laid the foundation of their phenomenal success by the recognition of that most vital principle of business success ; namely, the direct relation of producer and consumer.

No other dealers in Office Furniture and Filing Devices in this country, so far as we know, make their own goods and sell them exclusively direct to the consumer, and we are the only ones selling similar goods to the user who are not either jobbers of goods made by various manufacturers, or who make only a portion of the article they sell.

The Globe Company has long been the leader in the quality and extent of their stock of the different Labor Saving Devices, with which modern offices are daily becoming better equipped. No one who has any regard for the time and labor of himself or his subordinates, will think of doing business without all the devices for systematizing and arranging the different classes of papers, and the information contained in them, that can be used to advantage.

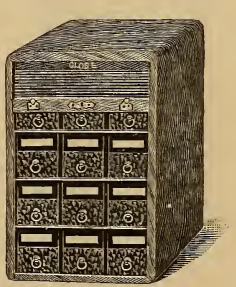
For the systematic preservation of papers, the Globe Filing-System is without a peer, and any paper or letter that



A DRAWER FROM A GLOBE CARD INDEX SYSTEM CABINET.

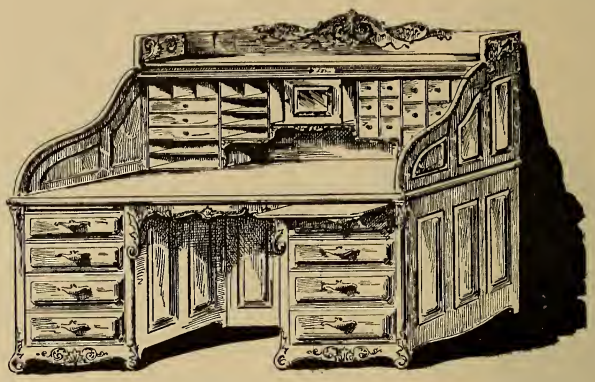
may be wanted, can be produced instantly, and without any of the annoyance and inconvenience of handling a large quantity of more or less dusty paper.

It is frequently the case that one wants a more comprehensive system of filing than can be gotten by a division of matter, either by name or subject. Constantly we desire to index a paper under not only the name, but also the subject as well, and, in addition, make many cross references thereto. It is manifestly impossible to have one paper in more than one place, and we are therefore compelled to use an outside index or reference. For a complete and comprehensive index of this character, nothing has yet been devised which can compare with the Globe Card Index System. Originating as it did from the necessity for indexing the contents of libraries, the uses of it have spread to almost every branch of the professional and



PIGEON-HOLE FILES.

business world. In no profession is its use more advantageous than to engineers. For keeping track of the cost of construction and maintenance, as an index for any facts worth preserving, to classify and arrange any growing lists of names or things, its advantages are apparent on the most casual inspection, and the long use simply confirms and strengthens the opinion formed in the first place. Anyone who has ever tried to keep an index of facts, or arrange a growing list of names in a book index, must have recognized its limitations and vexations.



A MODERN DESK.

All this labor, forethought and worry can be avoided by the use of the Globe Card Index System. Its advantages are manifold. Reference to the same paper can be had under as many names or subjects, or both, as may be deemed desirable ; everything pertaining to a certain subject can be kept by itself, and this subject can be again sub-divided into as many parts or sub-subjects as may be necessary. The fact that this system can be extended and elaborated indefinitely, is its chief advantage. Dead matter can be instantly removed from the index, without disturbing anything else, and additional information can always be put in its proper place, even down to the minutest subdivision.

LETTER FILE FOR SMALL SPACE.

After matter has once been written, it is never necessary to re-write it ; and should a re-arrangement of the index seem at any time desirable, it can be accomplished by simply transferring the cards to the proper location.

No matter how complete the stock of Filing Devices and Business Furniture is, there is a constant demand for things to be made, according to the ideas and requirements of individual cases. We have built up a large business in doing work of this character, and will always be pleased to make estimates and submit designs for anything of this kind that may be desired. We also solicit correspondence upon anything relating to indexing or the systematic arrangement of office methods, that our wide experience in these matters would render us competent to answer.

Correspondence from the Eastern Seaboard, and its adjacent Territory, should be addressed to our Eastern House, at No. 42 Beaver street, New York, where a full line of samples can be seen, and all information desired can be obtained.

We issue a catalogue, fully illustrated, containing over 100 pages, and would be pleased to send you one, and quote special net prices, upon receipt of information as to what your requirements may be.

THE GLOBE COMPANY,

Cincinnati, O. 42 Beaver street, New York.

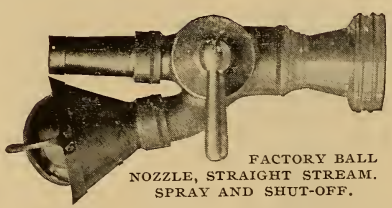
THE BALL NOZZLE—A MARVELOUS CONTRIVANCE.

From the Baltimore Underwriter.

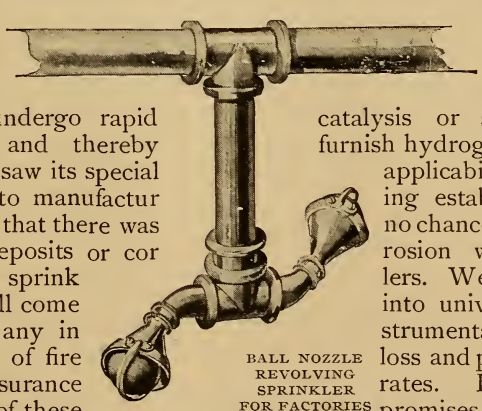
IN the happening of the unexpected, a contrivance for a new and curious application of the water that is still our main reliance, has been added to our fire fighting equipments by the American Ball Nozzle Company of New York City.

We do not pretend to see further through a grindstone than other people, nor do we claim a higher grade of intuitive perception than the average; but when we first saw the Ball Nozzle in operation, its capabilities flashed upon us in a twinkling. We saw at once that the funnel-shaped stream would extinguish flame without drowning and ruining valuable property. We saw at a glance that it is a powerful smoke driver; and in forcing smoke before it, it will enable a fireman holding the pipe to advance at a rate that has heretofore been impossible in the rescue of imperiled lives. We saw that in contesting the spread of a fire, it covers the entire blaze with a deflected and a distributed sheet instead of throwing a circumscribed single stream in spots so to speak. We saw that without lessening the amount of water delivered it was raining drops—not intangible mist that would undergo rapid catalysis or separation into its original elements and thereby furnish hydrogen to add new fuel to the flame. We saw its special applicability to hotels, to ships, to theatres, to manufacturing establishments, to lumber yards. We saw that there was no chance for impairment by the sedimentitous deposits or corrosion which so seriously damage automatic sprinklers. We saw, in short, that sooner or later it will come into universal use, and that it will, more than any instrumentality now employed, minimize the ratio of fire loss and pave the way for reduction of fire insurance rates. In the steady and gradual realization of these promises we do not pretend to talk in the "we told you so" style. Thousands of intelligent lookers-on must have interpreted these forecasts just as plainly as they appeared to us.

THE BALL NOZZLE.



FACTORY BALL NOZZLE, STRAIGHT STREAM. SPRAY AND SHUT-OFF.



BALL NOZZLE REVOLVING SPRINKLER FOR FACTORIES AND STANDPIPES.

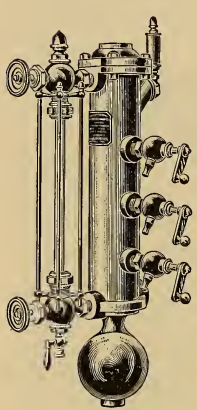
While it is a mysterious principle involved, and difficult to explain why the ball remains against pressure ; whatever the cause is, the fact remains ; and at one bound, as it were, the ball nozzle has become one of our most valuable possessions. It is destined to take a place in the fire extinguishing equipments as indispensible as that of the telephone in the transmission of intelligence.

AMERICAN BALL NOZZLE COMPANY,
837-847 Broadway, New York.

SAFETY WATER COLUMNS.

THEIR TRUE VALUE FROM AN ECONOMIC STANDPOINT.

By A. J. Wright.



THE argument of economy is a threadbare one, and he who uses it courts ridicule, and must be prepared to defend the proposition, but if the recent developments at Niagara Falls enforce proper consideration of the subject on the part of the steam user, that influence will not merely be of assistance to me in this connection, but will hardly be less valuable to the manufacturers of the United States than the direct results, for most of the "economy" as practiced in the present age, instead of being "the road to wealth," is a short cut to the poorhouse, and accounts for a very large part of the ninety-five per cent. who fail in business.

There is no room here in which to pay respects to that large class of steam users who willingly, but unwittingly, pay the coal dealer over and over again for appliances which they feel too poor to buy, under the erroneous impression that fuel, no matter how much it takes, is a necessary expense ; or to those who will renew their boiler plant, when the old boilers are worn out, because they consider it necessary to do so ; but, ridicule the argument of economy as much as you may, the fact remains that steady water at the proper level in a steam boiler saves coal, saves the boiler, and obviates repairs, all of which cost money.

Each of these savings is greater and more important than would at first be supposed. The saving of fuel depends very largely upon the location and consequent cost per ton, but being continuous, no matter how small, it is important, and as applied to a safety water column may be realized to some extent, at least, when the fact is taken into consideration that a saving so small as five cents per day per boiler, will agregate a saving equivalent to a dividend of 75 per cent. to 100 per cent. per annum on the cost of the appliance.

With proper care and steady water, a well made steam boiler, instead of being short lived and expensive to maintain, would be practically indestructible. A clean boiler is not burned with the water at the proper level, nor is it racked and strained and worn out by contraction and expansion, if the water is carried steadily ; nor is there trouble even with leaky tubes, under ordinary circumstances. It follows therefore that the question of the value of safety water columns hinges upon the question as to whether their use does, or does not result in steady water. I know of no better way in which to settle that question than by bringing it home to every steam user. What therefore would be the result if you had safety

water columns in use in your plant? If you had them, and your employees were so blind to their own interests as to allow these columns to whistle, you would hear the whistles and hear them frequently, and your engineer and superintendent and everyone else interested would hear them. Remembering that the alarm points are at the upper and lower gauge cocks, extremes which the water line is never supposed to reach ; and remembering that the water tender has the water gauge and three gauge cocks on each boiler for his guidance ; and remembering that fuel is being wasted, irregular power is being furnished, and that your boilers are being worn out more rapidly than they can be in any other way, by reason of the expansion and contraction incident to unsteady water, would you tolerate any such action on their part?

The logical conclusion is that you would say to these employees, if they were so lacking in personal pride as to furnish an occasion for your doing so, that the water gauge and gauge cocks are there for their guidance, and that you expect them to keep the water at least within the prescribed limits, thus keeping the whistles quiet, and that their failure to do so would at least call for an explanation ; and the actual fact of the matter is that personal pride on the one hand, and discipline on the other, causes any class of help that has any right to be tolerated in a boiler room, or to have a place of responsibility, to watch the water closely and continuously, and thereby to carry it steadily as nearly midway between the two alarm points as possible, for obvious reasons.

What then is the true value of the safety water column? We will not mention the uncertain value of lives lost ; the average loss by steam boiler explosion which has been placed at $3000, nor the extreme cases where the loss was many times greater, as for instance at Shamokin, Pa., where twenty-seven of thirty-six boilers exploded on October 11th, 1894, with an estimated loss of $100,000, but will ignore the question of explosions entirely.

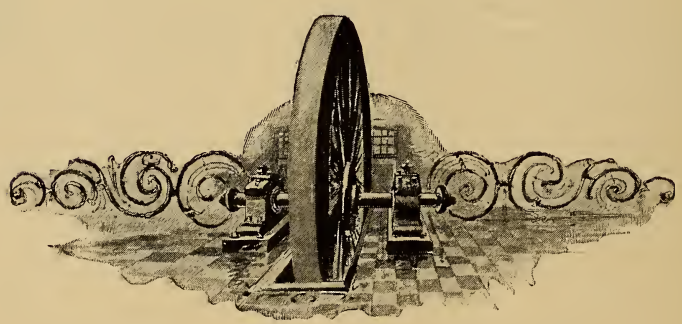
There can be no doubt that the steady water resulting from the use of these appliances increases the durability of the boilers, decreases the cost of maintenance, and reduces the fuel account. If the life of a boiler costing $1000 is thus prolonged 25 per cent., the safety water column effects a saving of $250 for its purchaser in this way alone, and if it saves $15 per year in repairs, the aggregate in twenty years, from this source, would be $300, and this estimate is probably not high, for repairs to leaky tubes, burned crown sheets, etc., etc., are never inexpensive, and they are practically unknown where safety water columns are used. Add to this as small a saving as you wish, or say, 5 cents per day for fuel, and counting three hundred working days to the year, you have another saving of $15 per annum, or $300 more, during twenty years, the period selected for convenience for this estimate. Here is a saving of $850, with explosions left out of the consideration, along with the general protection to life and property, all resulting from the use of an appliance which costs on the average about $20. It may be said that this estimate is extravagant. Taken as an aggregate it looks so, but taken item by item you will admit that it seems to be reasonable, but cut it in two and divide it by ten and you still have a return of 200 per cent. per annum on the investment. Divide it again and still again by ten and you still have left, after all this dividing, a return of 10 per cent. per annum, or the equivalent of a dividend sufficient to delight any financier. Is there any practical difference between dividend saved and a dividend earned? Make enough such investments as this and the dividends will take care of themselves. I believe that I have established the fact that it is not the safety water column but getting along without it that is expensive.

All these remarks are made with special reference to the Reliance Safety Water Columns, appliances which have been on the market since 1884, and which are in general use, and known to be reliable, for it is obvious that the desired results cannot be secured through the medium of an unreliable appliance.

Space here is too limited and too valuable to justify a detailed description of these columns, but it is in order to say that their success is due largely to the fact that the floats are reliable, less than 2 per cent. ever either filling with water or collapsing—and even these being replaced free of charge, no matter how long they may have been in use. Without reliable floats no safety water column can be depended upon for anything except trouble and expense. Hardly less potent in securing success for the Reliance Columns is the sediment chamber, which obviates trouble from sediment, and keeps the glass and gauge cocks clean, a feature possessed by no other safety water column, which is pronounced by no less authority than President J. M. Allen, of the Hartford Steam Boiler Inspection and Insurance Company, to be one of the finest ideas ever brought to his notice in connection with a steam appliance. Other points of superiority are the short and direct outlet to the whistle and the mechanical construction and workmanship. Everything is of mechanical proportions, the parts all being equally and sufficiently strong, insuring freedom from trouble even with such minor details as the gaskets. Some idea of the construction of these columns may be had from the fact that they are constructed for use up to 250 lbs. pressure, with a factor of ten for safety.

Any information desired may be had from

THE RELIANCE GAUGE COMPANY, Sole Manufacturers,
No. 93 to 103 East Prospect street, Cleveland, O.



THE JAMES LEFFEL WATER WHEEL AT THE FALLS.

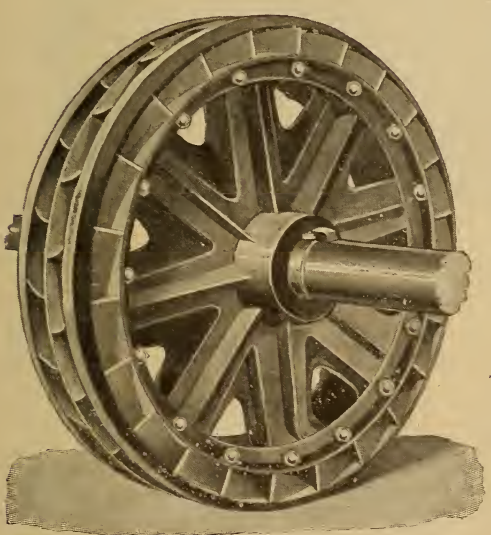
During the progress of the work on the Tunnel Company Development the Cliff Paper Co., lessee of the Niagara Falls Hydraulic Power & Manufacturing Co., contracted for two of the Double Discharge, Horizontal Shaft Water Wheels, specially designed and exclusively built by James Leffel & Co., of Springfield, Ohio. The illustration herewith shows only the runner or wheel proper of these turbines. The runners were designed of 66 inches outside diameter, that a required speed of 225 revolutions might be obtained, which was set forth in the specifications of the purchaser.

The central portion of the wheel consists of a hub and spokes built of iron ; and the circumference, or bucket portion, of the best bronze. The gates and portion of the guide casing are made of steel, and the water chamber surrounding the guide casing, of cast and steel plate iron.

The water is admitted to the wheels at the bottom of the casing through a 6-foot pipe entering between the perpendicular draft tubes. The draft tubes extend from the centres of the horizontal shafts to the tail water, a distance of eighteen feet.

These Leffel wheels were built upon a guarantee to use not more than a specified quantity of water to each ton of wood pulp ground per hour ; and upon a contingency, that if the first wheel put in operation did not perform in every way satisfactorily, the second wheel would not be required or taken. Both are long since in daily practical operation, and are fulfilling all requirements of the guaranteed service, not only in the execution of the work, but in the durability of their construction.

Each of these wheels are of 1200 horse-power nominal capacity, but the diameter and style of wheel is capable of a far greater power ; they being limited in this instance to the particular powers required by the limited number of grinders of special capacity. The unusual diameter of wheels being necessary for the specific speed ; recently the Power Company aforementioned have purchased and put in operation another James Leffel Wheel of the same design, of 600 horse-power capacity.



THE WHEEL PROPER.

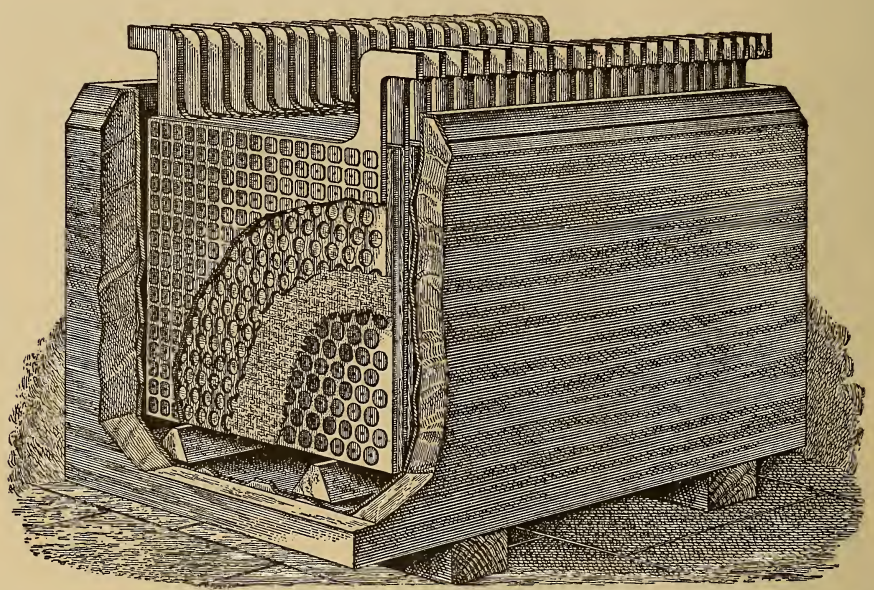
Four pulp grinders are driven by direct connection to each wheel shaft; two grinders being located upon each side of each wheel, while other additional machinery is driven also, but by pulley and belt connections. The wheels and their attachments are illustrated and described in detail in a paper giving a full description of the Cliff Paper Company's Mill, read at the annual convention, June, 1895, of the American Society of Civil Engineers, by Wallace C. Johnson, a member of that society.

Three pairs of Samson Turbines, built by the same Water Wheel Company, of 20 inches diameter, aggregating 1800 horse-power, are transmitting their power at the Falls of Juanacatlan, Mexico, a distance of eighteen miles, thus demonstrating the practicability of long transmissions and the future available power of Niagara Falls by that means.

JAMES LEFFEL & CO.

ELECTRICAL ACCUMULATORS.

How to operate economically electric plants under extremely fluctuating demands has become a question of great importance, owing to the enormous increase in the number and magnitude of such installations for both lighting and railway work. It is unnecessary to demonstrate the high efficiency and consequent economy of a generating plant working under a constant load as against one working under a varying load. The problem has been how to convert a fluctuating load into a steady one. Electrical storage is of course the most feasible way of accomplishing the desired result; heretofore the high first cost and the expensive maintenance have hindered the application of storage batteries for this purpose. Until quite recently the first cost of a storage battery installation was approximately three times that of a direct generating plant, including boilers, engine and dynamo; to-day, owing to the decrease in the cost of manufacture resulting from a larger demand for batteries, together with a more perfect battery capable of discharging at high rates without undue deterioration, a storage battery plant can be installed for less than two-thirds the cost of a direct plant of the most modern and approved type, and the depreciation on the battery will



CHLORIDE ACCUMULATOR, MANUFACTURED BY THE ELECTRIC STORAGE BATTERY CO., PHILADELPHIA PA.

be less than on direct apparatus. Consequently in stations where the maximum load is more than double the average load, the introduction of a battery connected across the line in multiple with the generators will allow of discarding between forty and fifty per cent. of the generating capacity, and enable the remaining portion to be operated at a constant load, and consequently at maximum efficiency. Great economy can be shown in all stations, in proportion to the variation in load; the greater the variation the greater the benefits derived from the application of a battery. The battery would be so arranged that it would charge when the demand for power on the line is less than the output on the generators, and will discharge when the power demanded is greater than the generator output, thus automatically transforming a variable demand into a constant one. Another advantage gained is the higher efficiency of the system owing to an approximately constant voltage on the line. Not the least of the advantages to be derived from the application of a storage battery is the great reliability resulting from its use, owing to its ability in case of accident to the generating plant to take up for short periods the whole of the load.

The production of a cheap, efficient and durable storage battery has opened a new field of electrical industry, which it has heretofore been impossible to enter, owing to the limitation of direct current distribution, which, without storage, is as a gas works would be without a gas holder.

THE ELECTRIC STORAGE BATTERY CO.
Drexel Building, Philadelphia, Pa.

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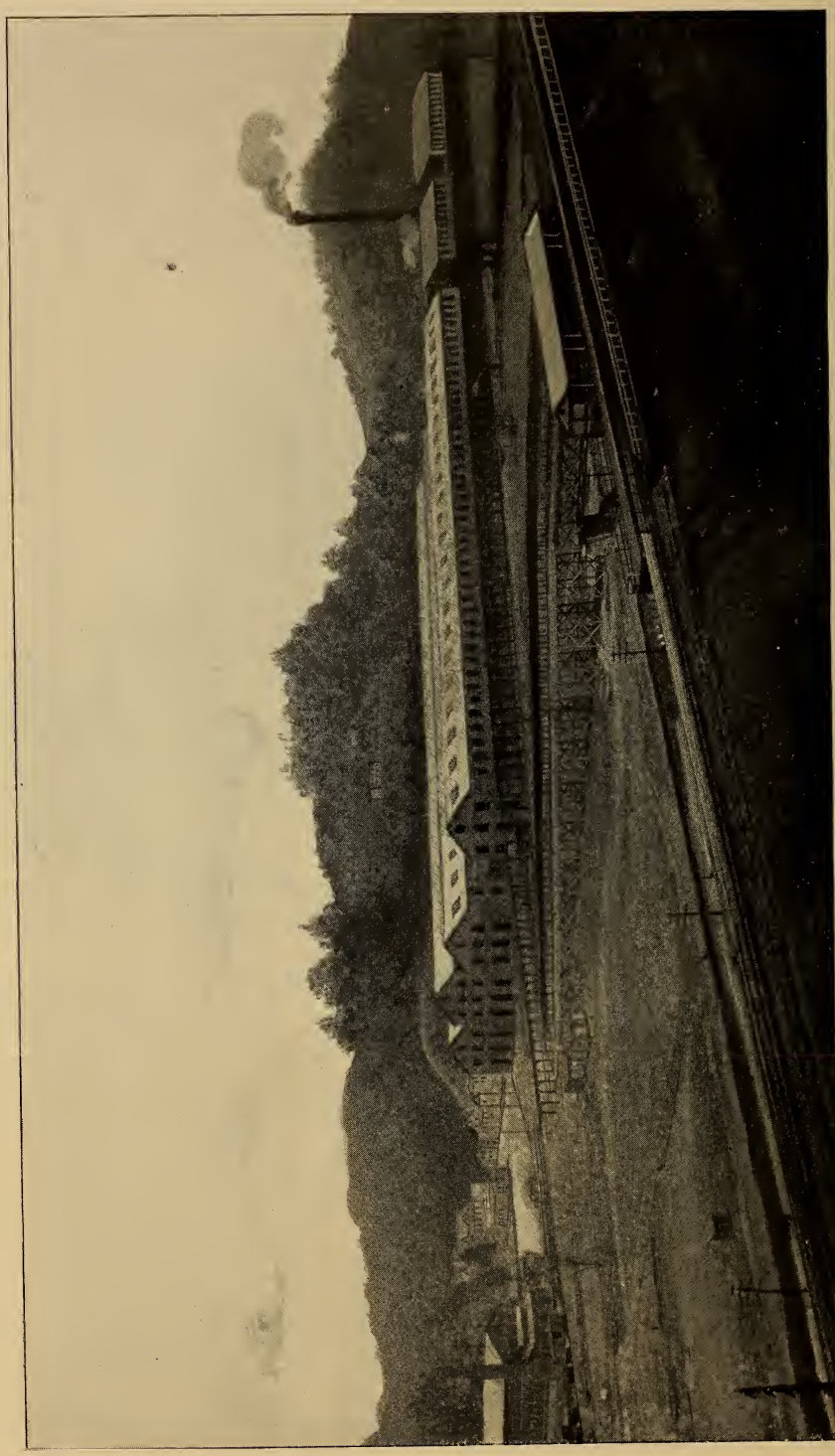
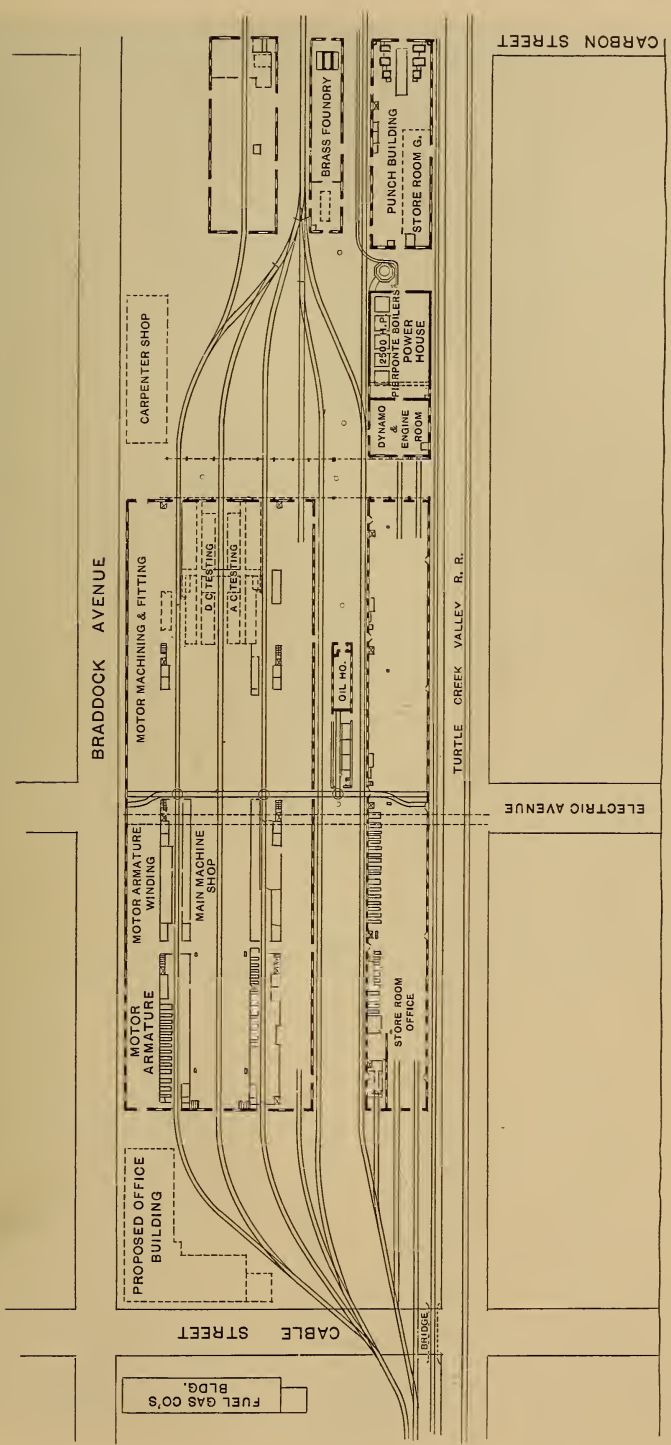
TESLA MOTORS IN A GREAT MANUFACTURING ESTABLISHMENT.

ONE of the striking features of the remarkable industrial development resulting from the extended and intelligent use of steam, which has done so much to make the record of the nineteenth century memorable, is the evolution of great industrial establishments employing thousands of hands, and combining the labor and skill of the employees with the best machinery known to the mechanic arts. Of such establishments one which is, perhaps, among the largest, one that is certainly among the newest, and one which is of especial interest to all who intelligently observe the tendencies of industrial evolution in America, is that recently completed by the Westinghouse Electric and Manufacturing Company at East Pittsburgh, a new station on the main line of the Pennsylvania Railroad, twelve miles east of the Union Station at Pittsburgh. Many features are perhaps no less interesting to the student of social economy than are others to the practical manufacturer, while all who are interested in recent progress in the development of the applications of electricity to the lighting of our cities, the propulsion of our street cars, and especially to the operation of machinery in mills and factories, can here find much to study with interest and profit. But to the manufacturer and engineer the feature which is most striking and of special interest is the use of electricity to drive all shafting and machine tools, and to perform other work necessary in large manufacturing establishments. This is here accomplished upon a scale not previously attempted. A power plant centrally located with reference to the various shops, and equipped with boilers, engines and electric generators aggregating 2500 h. p. is used to supply current to a large number of motors throughout the shops, conveniently located with reference to the machinery which they are employed to drive. It is believed that the efficiency, flexibility and economy attained are superior to anything previously realised in distributing power in large mills and factories. The motors employed for the purpose are of the latest pattern of what is beyond question the most interesting and valuable type of electric motor known,—the celebrated Tesla alternating current motor, invented by Nikola Tesla, and developed by the able technical staff of the Westinghouse Electric and Mfg. Company.

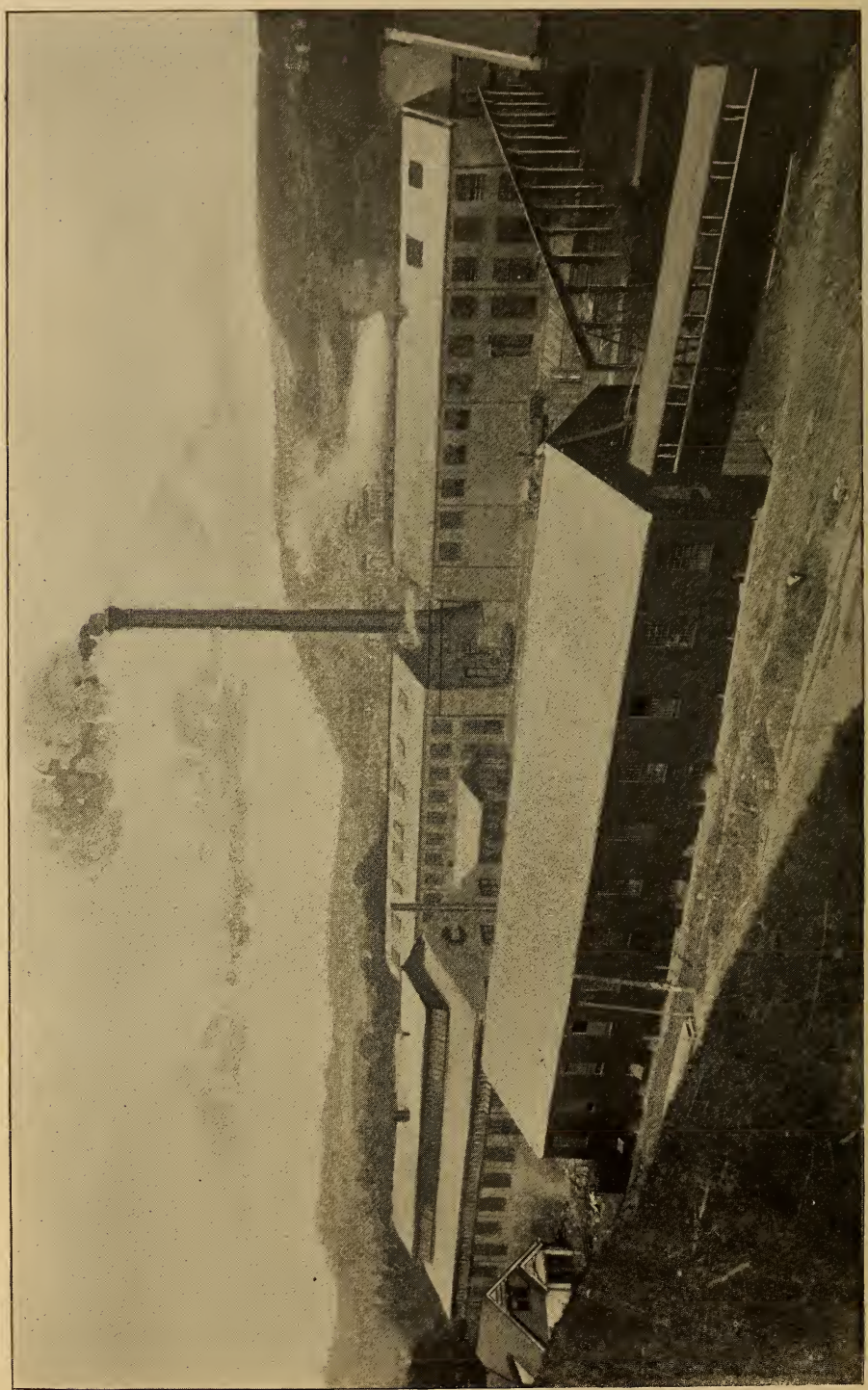
It is the especial object of this article to call the attention of those interested in the progress of the mechanic arts, and especially of those who may have occasion to investigate the problem of the distribution of power from central stations, to the method and apparatus here used, in the belief that it is an object lesson not only of scientific interest but of great practical value. A year ago the Westinghouse Electric and Mfg. Company (at that time employing about three thousand hands) was operating three factories, located respectively in Pittsburgh, Pa., Allegheny, Pa., and Newark, N. J. The business of the company had outgrown the capacity of the old shops, which were, moreover, somewhat scattered and inconvenient for the most economical manufacture of electrical apparatus. Realising the advantages of concentration, and desiring to carry out certain improvements in methods of manufacture, and especially in shop facilities, the company purchased a tract of land located, as has been said, about twelve miles from the centre of Pittsburgh, on the main line of the Pennsylvania R. R., with the intention of there erecting new shops, with especial reference to economy in manufacturing. It was determined that no expense should be spared in making these shops a model of the best practice of the day. The tract of land purchased embraces forty acres, and is in the form of a rectangular block, having a frontage of 2300 ft. along the line of the Pennsylvania, with ample railroad facilities to and



A GENERAL VIEW OF THE SHOPS OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, PITTSBURGH, PA.

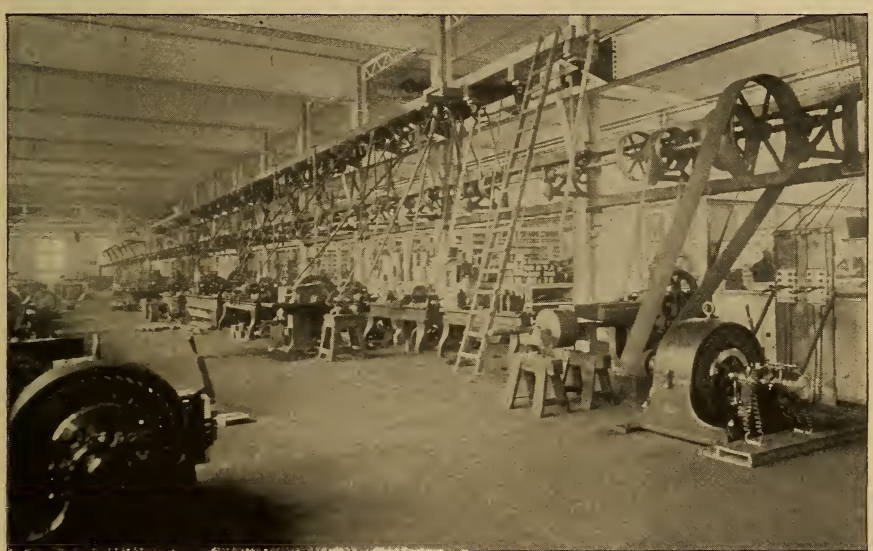


A PARTIAL PLAN OF THE SHOPS OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.] THE PROPOSED FOUNDRY NOT SHOWN.



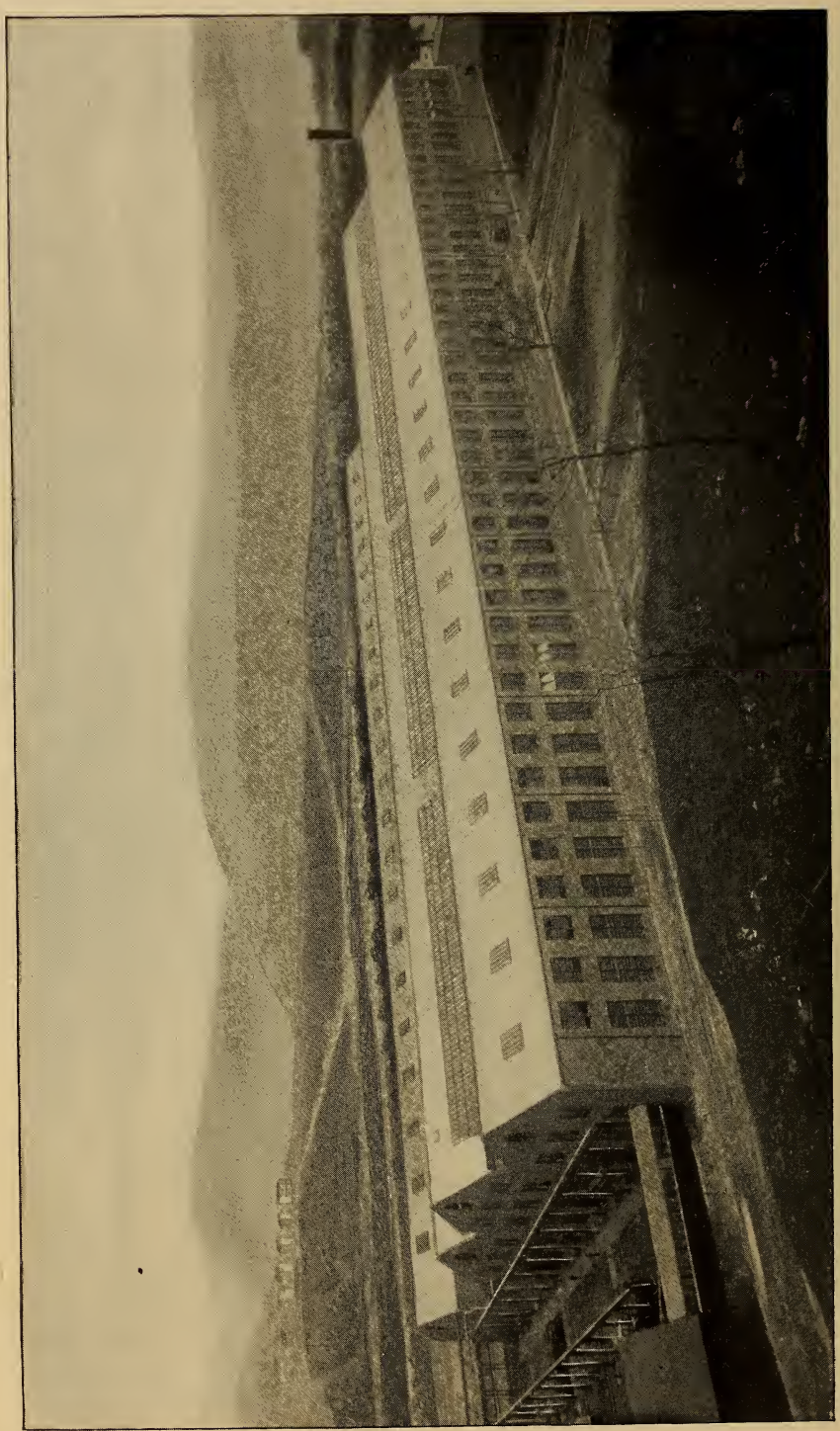
ANOTHER VIEW OF THE WESTINGHOUSE SHOPS, SHOWING THE POWER HOUSE.

on the ground. Page v shows a map of the property, and from it can be seen the relative location and size of the eight buildings that are now erected, which in the order of their magnitude are the Machine Shop, the Warehouse, the Pattern Shop, the Blacksmith Shop, the Power House, the Drying and Dipping Shop, and the Brass Foundry. The Main Foundry, which as yet has not been erected, and is not shown in the plan, will be 150-ft. wide and 750-ft. long. The Machine Shop is 754-ft. long by 231-ft. wide, the ground floor covering four acres, while the galleries are about three acres in extent. The photograph on page iv is a general view of the shops taken from a hill south of the Pennsylvania R. R. tracks. In the foreground the line of the railroad and the station and covered way,—erected for the convenience of the employees,—are seen. The building nearest the point of view is the Warehouse 754 ft. in length and about 76-ft. wide. The western end of the second floor of this building,—that is, the end nearest the point from which the photograph was taken, contains the offices of the administration, engineering and drafting departments of the company, while the eastern half is devoted to the



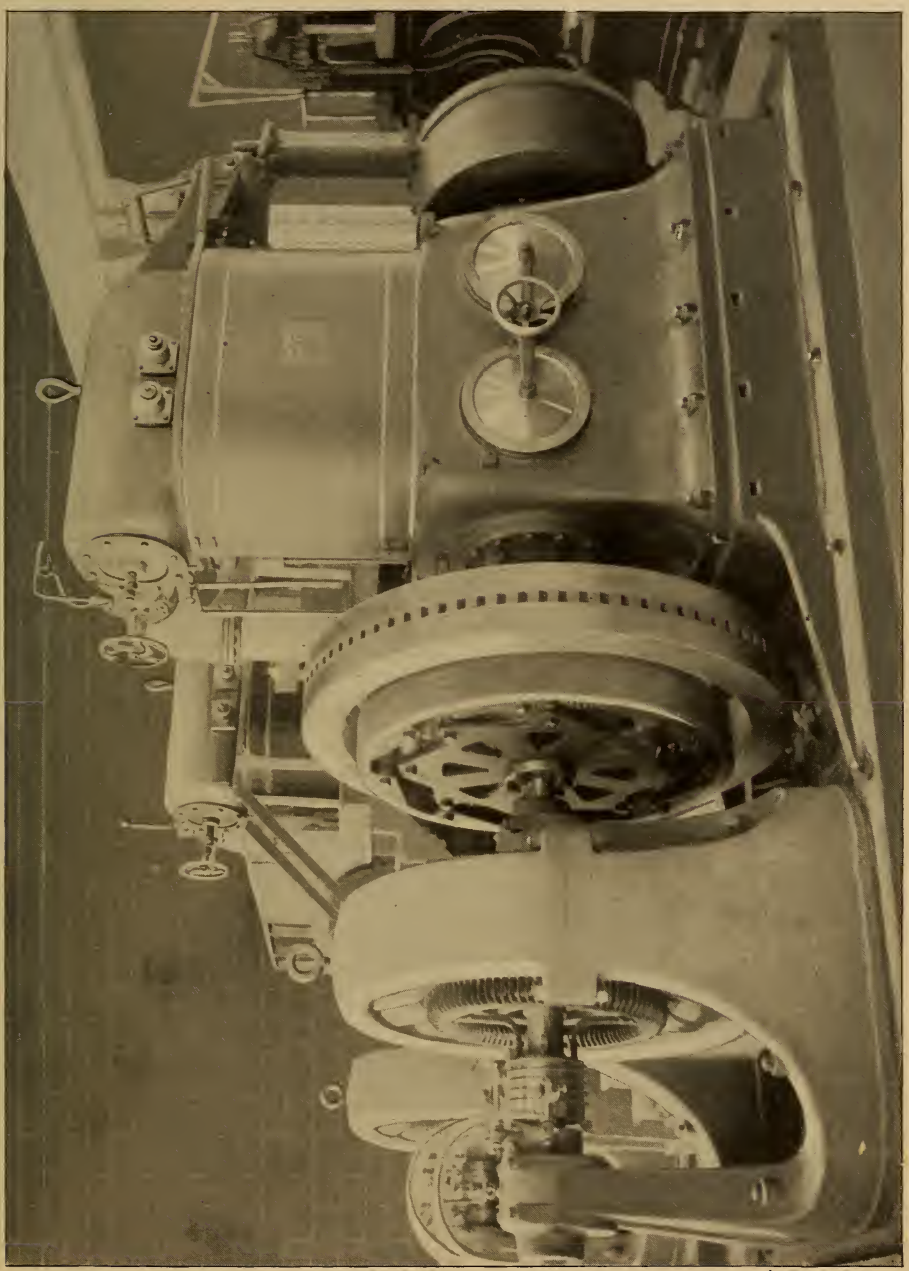
A TESLA MOTOR DRIVING MACHINERY IN THE WESTINGHOUSE SHOPS.

manufacture ot meters, arc lamps, switchboards and similar apparatus. Beyond the Warehouse, and parallel to it, is the Machine Shop, the western end of which is shown in the photograph. This building is divided by the roof lines and the columns supporting them into three aisles of equal width. Railway tracks in each aisle extend entirely through the building, and are connected by switches outside. The main aisle is open from the ground to the roof, and two 30-ton travelling cranes traverse the aisle from end to end. The side aisles contain a second story, and each is further divided by a row of columns supporting the second floor. These columns also serve to carry the runways for two 10-ton travelling cranes, a pair of cranes in each runway traversing the side aisles from end to end. There is a gallery bridge at each end of the Machine Shop connecting the side aisles. For communication between the floors there are ten stairways and ten elevators, each of the latter being driven by belt from a 10 h. p motor. The side walls of the Machine Shop, as well as those of the Warehouse, Power House, Blacksmith Shop and Punch Shop are constructed of brick, the brickwork enclosing the steel columns which support the floors and roof. The girders and roof of the building



LOOKING AT THE WESTINGHOUSE SHOPS FROM THE NORTHWEST.

Tesla Motors in a Great Manufacturing Establishment.



OF THE POWER PLANT, SHOWING WESTINGHOUSE ENGINES CONNECTED DIRECT TO TWO-PHASE GENERATORS.

are of steel, wood being used only in the floors and window sashes. Ample window and skylight area is provided, and the shops are in all parts remarkably well lighted. There are twelve toilet rooms in the Machine Shop, six to each floor, and in every way the comfort, cleanliness and health of the employees have been considered.

The photograph on page ii shows a general view of the central hall of the Machine Shop.

The heating system is designed to warm the shops to about 60 degrees during the coldest weather, and the fan system of hot air heating is employed. The Machine Shop contains 9,171,000 cubic feet of air, and the heating system is designed to change and rewarm this amount in twenty minutes. The amount of heating surface in the six heaters used in the Machine Shop is about 20,000 square feet. Each of the six fans is driven by a 30 h. p. motor, and the heated air is distributed throughout the shop by blast pipes, which are carried overhead.

The other buildings are heated in a similar manner.

The fire protection system of the various shops consists of a complete equipment of water mains supplied from a reservoir. These mains connect to the various stand-pipes and hydrants throughout the grounds. The employees are well drilled and supplied with a full equipment of apparatus for extinguishing fires.

The photographs on pages vi and viii are views of the shops taken from the side opposite the Pennsylvania tracks. In taking the former the camera was pointed south southeast, and in taking the latter east southeast. In the former the Power House with its tall stack is conspicuous, and beyond it is the Punch Shop, where the steel plates used in constructing transformers and the armatures of generators and motors are punched out of large pieces of sheet steel by powerful presses, the required forms being obtained by the use of steel dies.

The building in the foreground is the Pattern Shop, and the building beyond it and to the left near the Punch Shop is the Brass Foundry. In the photograph on page vi the Machine Shop and Warehouse are seen from a direction almost opposite that in which the photograph on page viii was taken.

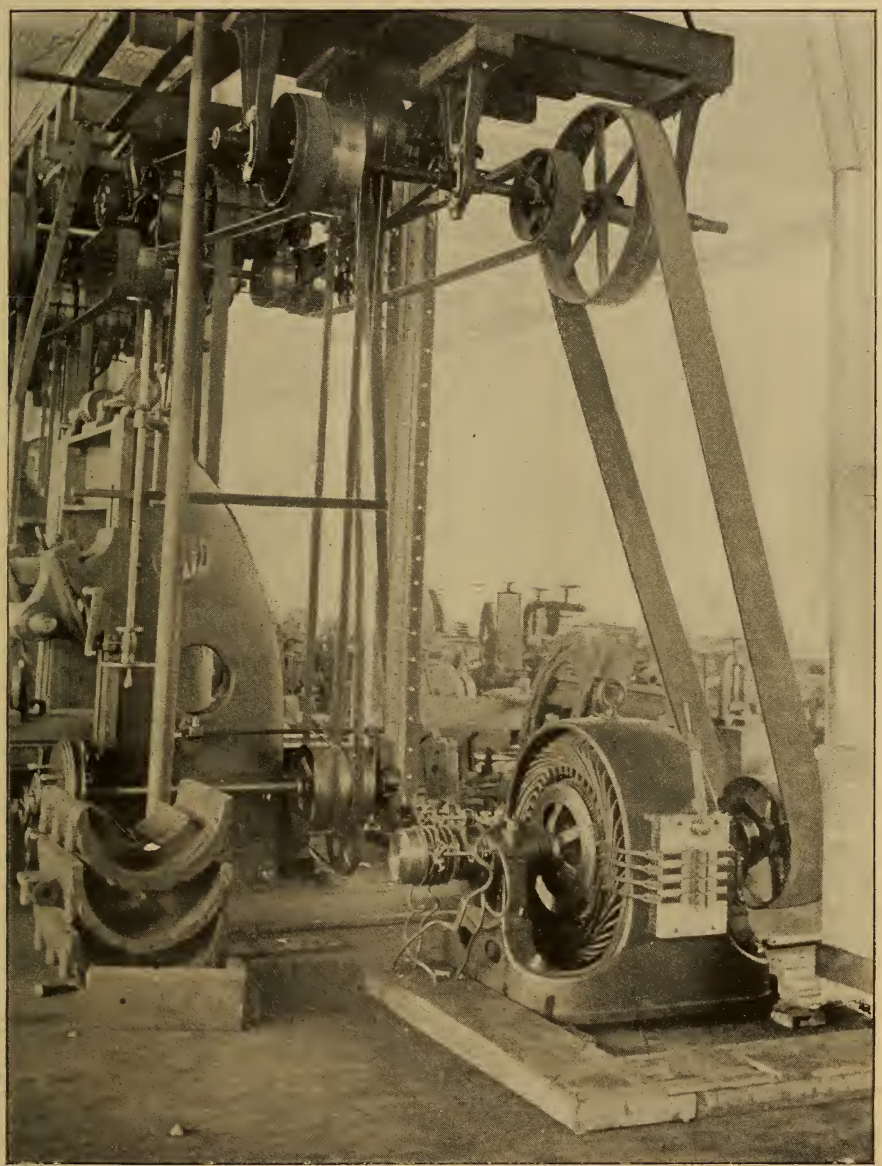
Nearly all the machinery used in these great shops, comprising upwards of 1250 machine tools, is operated by Tesla polyphase motors, supplied with two-phase alternating current at a frequency of 25 cycles per second. This is the identical system worked out by the Westinghouse Electric and Mfg. Company, for the use of the Cataract Construction Company, in their great work at Niagara Falls. The alternating current generators are located in the Power House, from which current is conveyed by insulated conductors to motors conveniently placed throughout the various shops. The potential used is 200-volts, and this is supplied directly to the motors without the interposition of transformers. The line shafting throughout the buildings is divided into comparatively short sections, and motors ranging from 10 to 50 h. p. are employed to drive the sections ; in certain cases large tools will be separately driven by independent motors.

In the Power House three 500 h. p. two-phase generators, direct driven by Westinghouse compound engines, are installed. Two of these are shown in the photograph on page ix. They are driven at a speed of 250 r. p. m., and deliver current to two separate circuits, these currents differing in their time relation or phase by 90 degrees. They are separately excited, current for this purpose being derived from a small direct current machine.

The photograph on page vii shows a section of the machinery in one of the side aisles of the Machine Shop operated by a 50 h. p. Tesla motor. The photograph on page xi shows a similar motor driving some of the larger tools in the Machine Shop.

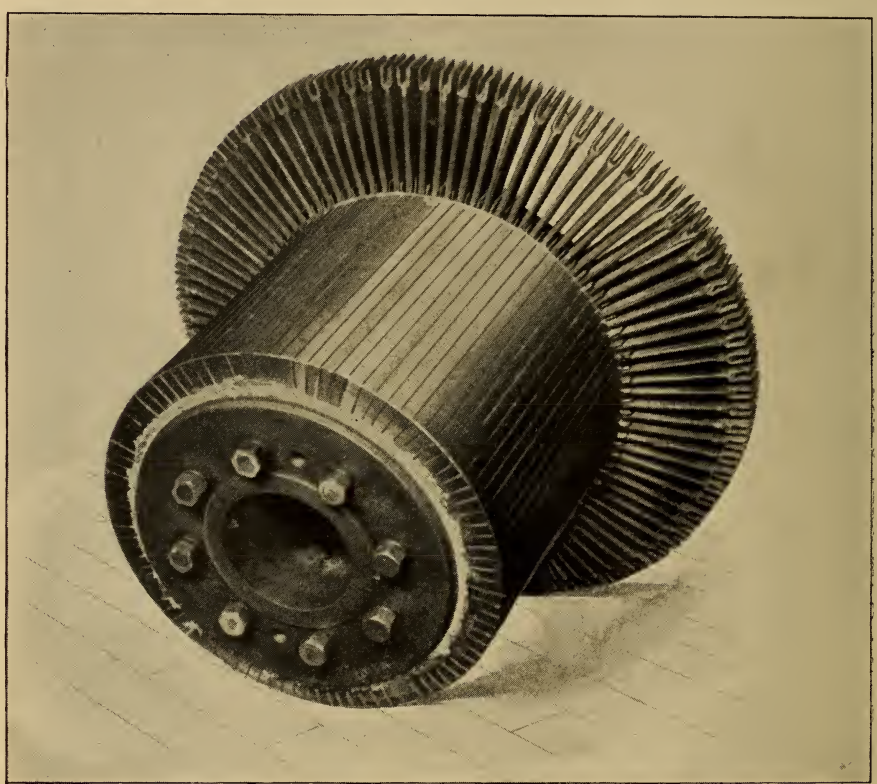
The improvement resulting from the sub-division of the line shafts and the introduction of motors to drive a large number of short sections of line shafting

Tesla Motors in a Great Manufacturing Establishment.



A 50 H. P. TESLA MOTOR DRIVING HEAVY MACHINERY IN THE WESTINGHOUSE SHOPS.

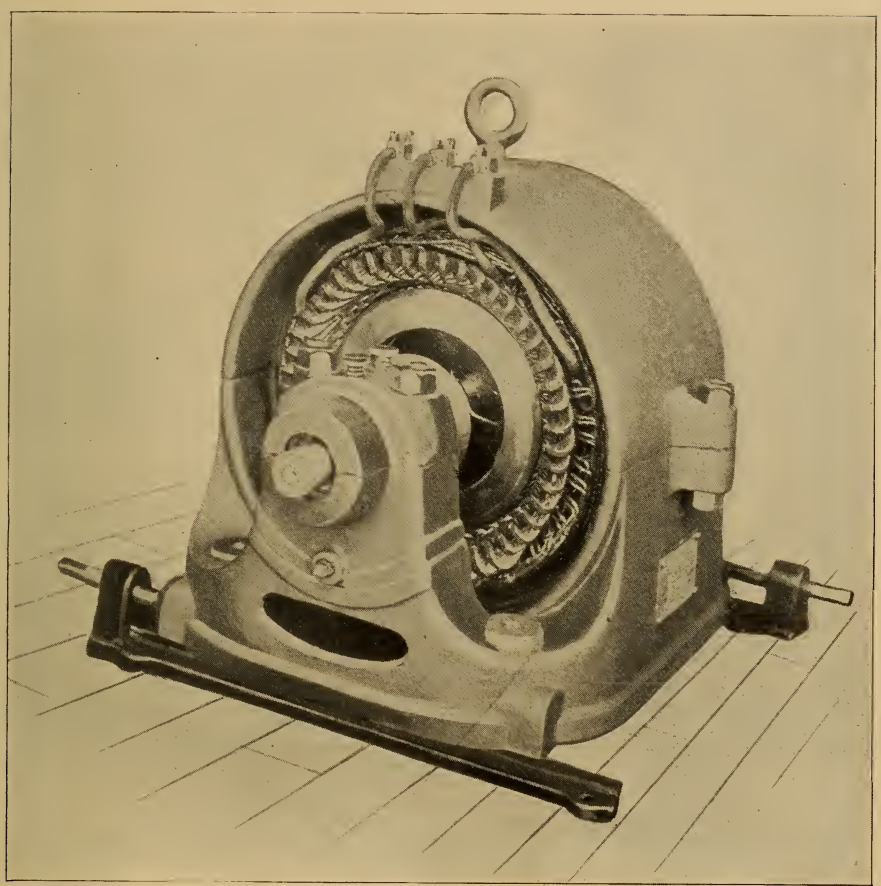
is remarkable, and deserves very careful consideration on the part of all interested in manufacturing establishments where a considerable amount of power is required. With shops as large as these the old method of supplying power to the tools by a system of line shafting and belts driven by engines located at a given point would be scarcely practicable. If the length, size and cost of the line shafts were not prohibitive the losses involved would certainly reduce the efficiency of the system to a very low point. An alternative method sometimes adopted is to use a number of engines located at different points, and supplied with steam from a boiler plant central with reference to these points. This also means poor economy and involves many objectionable features. As compared with the central power



A MODERN COMMUTATOR FOR AN ORDINARY ELECTRIC MOTOR.

plant using line shafting and belts a very material gain is effected by the reduction of the amount of shafting, but to offset this the losses due to radiation from the steam piping must be taken into account, and it must also be remembered that the smaller engines are less economical than the larger ones, which may be used under the plan first described. More than this, in its relation to economy the greater amount of fuel required to develop a given amount of power is not usually the largest factor ; every engine must be looked after, and the cost of attendance where engines are located at a number of different points are used is greatly increased.

It is difficult to obtain accurate data in regard to the actual cost of power distributed throughout manufacturing establishments by these several plans, but



ONE OF THE TESLA MOTORS.

it is believed that, as compared with either of the two alternative methods hitherto used, the plan adopted in the Westinghouse shops reduces the amount of power required at the boilers by a large percentage.

But this is not the most important advantage realised; as compared with the plan of using separate engines the avoidance of the heat from steam pipes, tending to make the temperature of shops unbearable in hot weather, the saving of space, and the decreased cost and trouble of maintenance, are still greater gains ; and as compared with the distribution of power by line shafting from a central power house the elimination of the heaviest, the most expensive and the most troublesome part of the shafting are advantages of great practical value.

As we have said, the type of motor employed,—the Tesla polyphase type,—is one of peculiar interest and value. The object which Nikola Tesla sought to attain when he began the work which led up to the invention of these motors, which are now so celebrated, was the elimination of the commutator,—the weak point. and the most troublesome element in all direct current motors, which at the time Tesla began his work were the only motors available for practical purposes. Since that time much has been done to improve the construction of commutators, but they still remain the weakest element in direct current machinery, and when well made are very expensive. They are necessarily built up of a large number

of segments of copper, and each segment must be insulated from adjacent segments by insulation of ample strength for the potentials employed, and without the slightest crack or pinhole. Any failure to realise these conditions will cause a breakdown and interruption of service. Moreover, the constant rubbing of the brushes against the commutator, which is built up of segments of copper separated from each other by thin layers of insulating material, wears away both brush and commutator, and this wearing away is, in spite of the best construction, inevitably more rapid than in the case of the alternating current motor, where the brushes bear against the rings of a collector. The photograph on page xii shows an extremely well made modern commutator, and the photograph on page xvi illustrates a collector. The latter consists essentially of rings of metal, usually copper or brass, centred on the same shaft, and separated from each other by heavy rings of insulating material. The parts, as compared with the commutator, are relatively few, and the insulation can be as heavy as desired. In the larger Tesla motors collectors are used, but in the smaller ones even these are discarded. The photographs on pages vii and xi illustrate respectively a 3 h. p. three phase Tesla motor and a 50 h. p. two-phase Tesla motor, as manufactured by the Westinghouse Electric and Manufacturing Company, which Company is the sole owner of the United States patents issued to Nikola Tesla. In the 50 h. p. motor, as will be seen, the ring collector is used; in the 3 h. p. motor no commutator or collector is employed. It is possible to build large motors without the collectors, but this is done at a sacrifice of efficiency, which in some cases is very material. The collectors run without attention for almost indefinite periods, and are practically not objectionable.

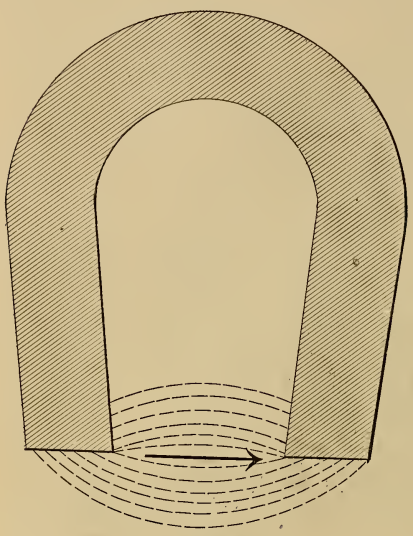


FIG. 1.

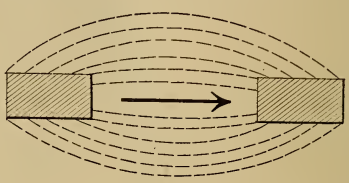


FIG. 2.

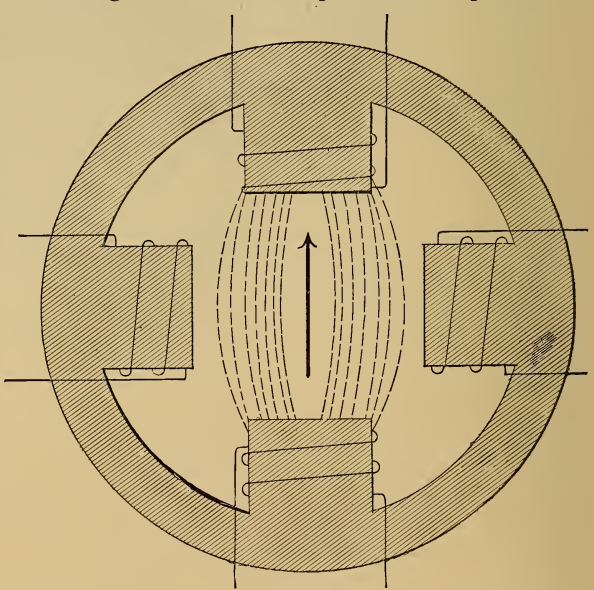


FIG. 3.

While the most marked advantage of the polyphase motor, as compared with the ordinary types of direct current motor, is in its mechanical construction and low cost of maintenance, the efficiency of those manufactured by the Westinghouse Company is very high, and as compared with direct current motors is especially high at partial loans. Every motor turned out of the shop is tested by a Prony Brake and its performance at various loads carefully determined, the results of the efficiency tests being plotted graphically.

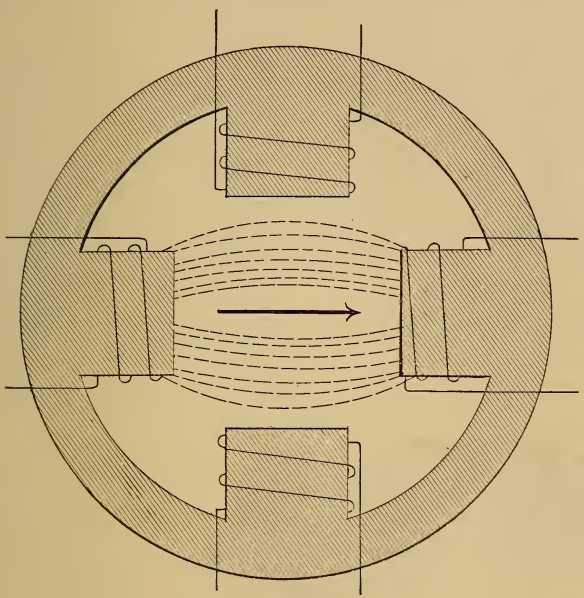


FIG. 4.

The writer has before him a number of these graphic diagrams, showing performance of motors of various sizes, and from these the following figures are taken:

The efficiency of a 10 h. p. motor, delivering half load (5 h. p.) is 79 per cent. ; under full load (10 h. p.), it is 84 per cent. ; and under an overload of 50 per cent. (*i. e.* when delivering 15 h. p.), its efficiency is 75 per cent. A 20 h. p. motor delivering 5 h. p. works at an efficiency of 78 per cent.; delivering 10 h. p. its efficiency is 84 per cent. ; and at full load (20 h. p.), its efficiency is 82 per cent. A 50 h. p. motor delivers 5 h. p. at an efficiency of 72 per cent. ; 10 h. p. at 81 per cent. ; 20 h. p. at 89 per cent. ; 30 h. p. at 91 per cent.; 40 h. p. at 91 per cent.; 50 h. p. at 89 per cent. ; and 60 h. p. at 88 per cent. A 1 h. p. motor delivers ¼ h. p. at 61 per cent. ; ½ h. p. at 72 per cent ; ¾ h. p. at 75 per cent. ; 1 h. p. at 73 per cent. and 1¼ h. p. at 69 per cent.

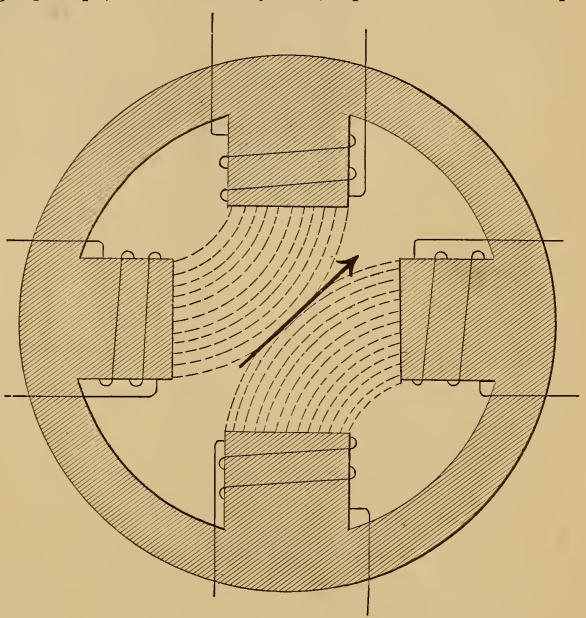


FIG. 5.

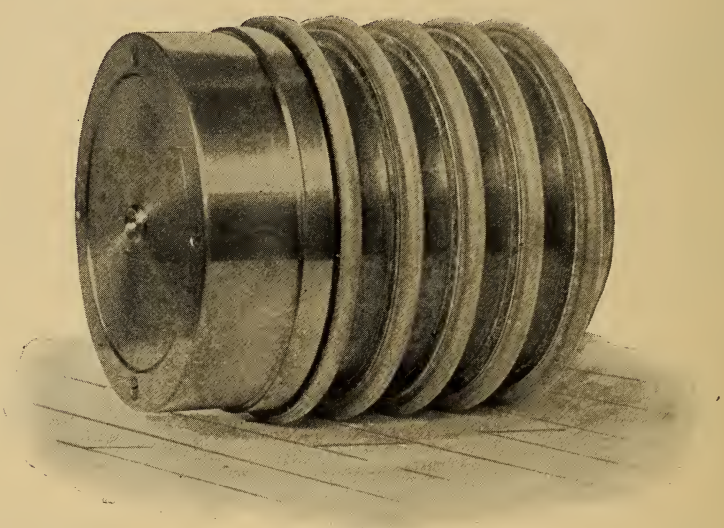
These motors are intentionally so designed that their maximum efficiency occurs at a load somewhat less than their rated output. This is thought desirable for the reason that motors in shop work are apt to run at somewhat less than their rated outputs, and the net efficiency of the plant is therefore

improved by so constructing the motors that they work at their best efficiency at from 10 per cent. to 25 per cent. less than the full loads which they are capable of carrying.

In using the polyphase system it should be noted that if the frequency selected be suitable, the shops can be lighted from the same circuits that are used to supply motors. The frequency adopted in the Westinghouse shops is 25 cycles per second, or 3000 alternations per minute. This permits incandescent lighting that is entirely satisfactory for shop work, but it is too low for arc lighting. A similar system of motors manufactured by the Westinghouse Electric and Manufacturing Company is designed for a frequency of 60 cycles per second, or 7200 alternations per minute, and this is adapted to both incandescent and arc lighting. The lower frequency possesses an advantage in reducing the speed of the motors.

The question is often asked what is meant by a rotary field induction motor, and the following simple exposition of the principles upon which these motors are based will be of interest.

The theoretical principle upon which the Tesla, or rotary field, motor is based



COLLECTOR OF A LARGE TESLA MOTOR.

is as simple and elegant as the practical apparatus in which it is utilized. The rotary magnetic field, which is the underlying principle of the motor, may be illustrated by a common horseshoe magnet and an ordinary compass needle. If the poles of such a magnet be placed directly over a compass, the needle will assume a position in the direction of the lines of force between the poles of the magnet. This is shown in Figures 1 and 2, the latter being a section across the end of the magnets. If the magnet be revolved, the direction of the lines of force revolves and the needle will follow this direction and will turn at the same rate that the magnet revolves. If current be passed through a coil around an iron core a magnet is produced, somewhat similar, but usually much stronger than a permanent magnet. An iron ring with four inwardly projecting poles may have windings placed on the several poles. If a current be sent through the coils on the upper and lower poles, a vertical magnetic field will be produced, and a magnetic needle pivoted at the centre of the ring will take a vertical position in the direction of the lines of force as in Fig. 3. If on the other hand a current

be sent through coils which are upon the other set of poles, a horizontal field wil be formed and the needle will take the position indicated in Fig. 4. The direction of the needle depends upon the direction in which the current is passed around the coils. In the latter case the needle may point either to the right or to the left, depending upon the direction of the current. If a current were passed through both sets of coils at the same time, the needle would assume a midway or 45 degree position between the poles Fig. 5. We may suppose that current is passed through the vertical coils in such a direction that the needle points upward and that this current decreases in strength, while another current through the horizontal coils gradually increases its strength. The needle will be drawn from the vertical position, Fig. 3, through the midway position, Fig. 5, to the horizontal position, Fig. 4, when the first current has ceased to flow. If now the current in the first coils be passed in the reversed direction, the needle will be pulled below the horizontal, assuming a greater and greater deflection until it points downward, when the current in the horizontal coils has ceased to flow. A continuation of this action will evidently cause the needle to revolve in obedience to the revolving resultant of the two magnetic fields. The currents which have been assumed to flow vary in intensity, increasing to a maximum and then decreasing, reversing in direction and again reaching a maximum, and then decreasing to zero, and are alternating currents. Moreover the two currents have their maximum values at different times, *i. e.*, they differ in phase, so that the maximum of one current occurs at the same time that the other current is passing through zero. The resultant action of alternating currents differing in phase is the production of a magnetic field which is constantly shifting its direction, similar to the shifting caused by the rotation of a permanent magnet. Such a shifting magnetic field may cause the rotation of a compass needle as illustrated above, or it may be made to act upon an electro-magnet, which will in general produce a much stronger action than can be secured by action upon a permanent magnet. If an iron core with copper windings be placed in the rotating magnetic field, currents will be set up in the coils and these currents will produce magnetic poles in the core. These poles will be drawn by the revolving magnetic field, producing rotation very similar to that produced in the compass needle.

A mechanical analogy of the rotary field motor is found in the cranks of an ordinary engine. If a shaft have a single crank the torque is not uniform and there are dead points. If, however, a second crank is placed at right angles to the first, this crank will have its maximum effort at the time when the first crank is on its dead point, and the resultant action of the two cranks is to give a uniform torque.

All of the various polyphase systems—the 2-phase, the 3-phase, the so-called monocyclic, etc.—depend upon this beautiful principle. In all of them we have a magnetic field which is the resultant of two or more alternating currents differing in phase, and which therefore revolves at a speed depending upon the frequency, as it were dragging the armature around with it.

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